‹e as that soul was whose progeny they are, nay they o preseive as in a
e purest efficacy and extraction of that living intellect that bred them

—*John Milton*

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The Journal of Bone and Joint Surgery*

American Volume

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American Volume

ROENTGENOGRAPHIC CHANGES IN NAILED SLIPPED CAPITAL FEMORAL EPIPHYSIS *

BY ARMIN KLEIN, M.D., ROBERT J. JOPLIN, M.D., JOHN A. REIDY, M.D.,
AND JOSEPH HANELIN, M.D., BOSTON, MASSACHUSETTS

In a presentation made by the authors[3] before the American Medical Association, Section on Orthopaedic Surgery, in June 1947 were submitted the clinical results of

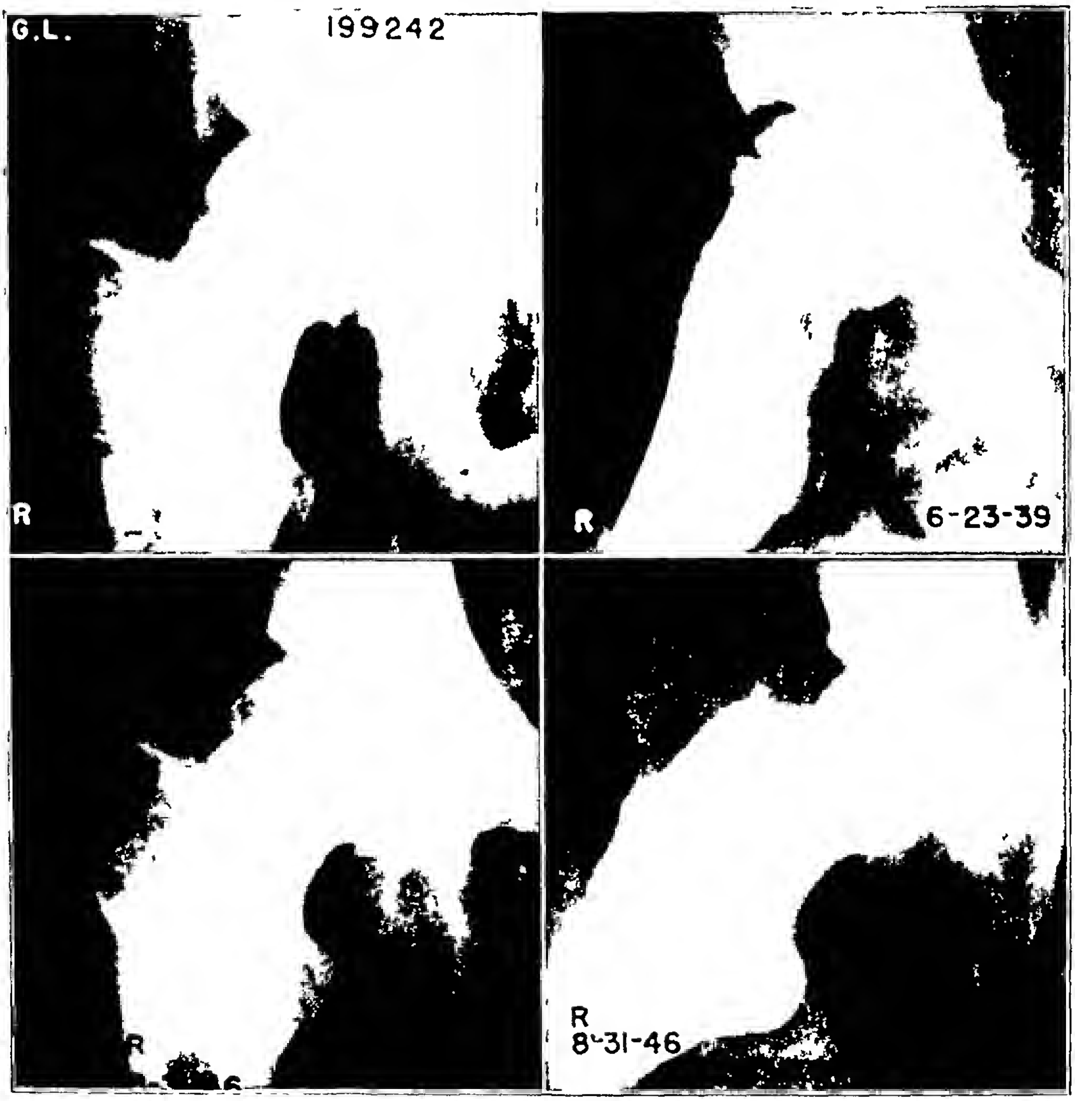

FIG. 1

Nailed *in situ*

G. L., a girl, aged thirteen years and eleven months, was operated upon June 26, 1939. (The age of each patient represents the age at the time the first roentgenogram was taken.) A minimal amount of slipping had occurred. The nail was removed nineteen months after operation. Seven-year follow-up.

* Read at the Joint Meeting of The American Orthopaedic Association, The British Orthopaedic Association, and The Canadian Orthopaedic Association, Quebec, Canada, June 3, 1948.

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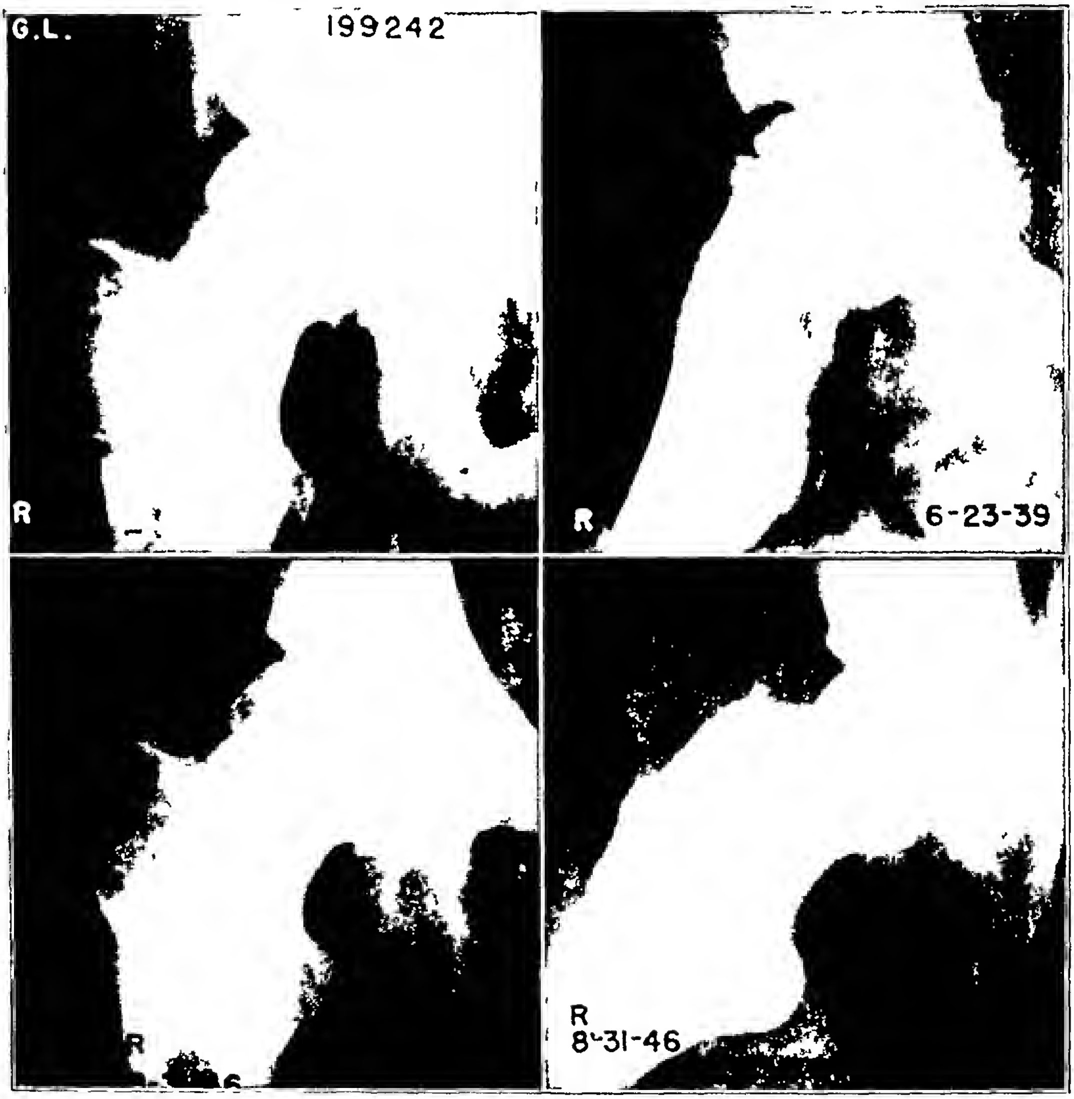

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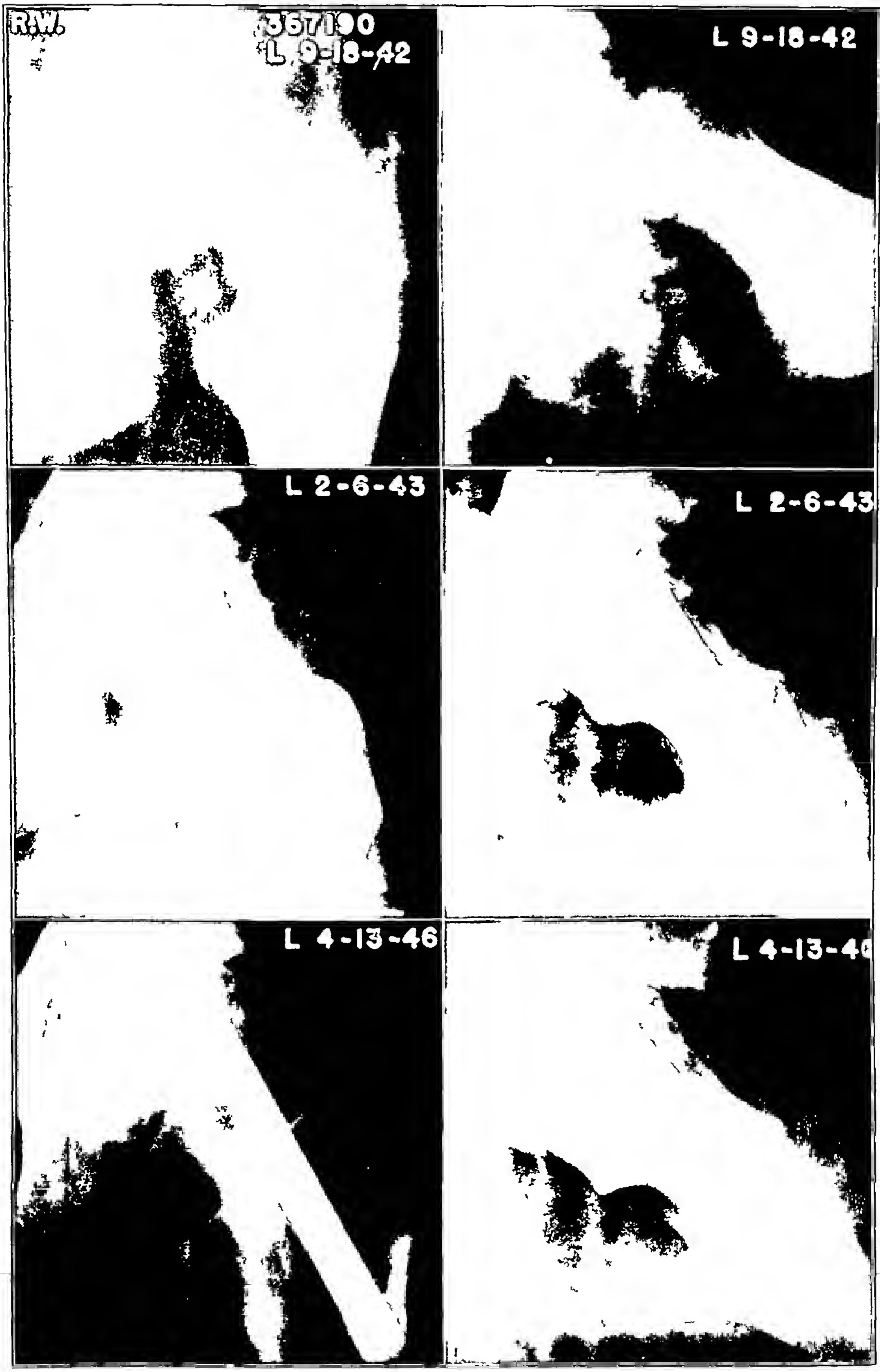

FIG 2

Nailed after epiphyseal osteotomy

(The term "epiphyseal osteotomy" is used to designate the procedures of arthrotomy and osteotomy through the epiphyseal plate, prior to reduction)

R W , a male, aged fifteen years and three months, was operated upon September 22, 1942

(*Continued on page 3*)

FIG. 2 (Continued)

Initial anteroposterior and lateral views, taken September 18, show slipping of 1.5 centimeters. Following satisfactory reduction and nailing, there is a defect visible at the superior junction of the head and neck. In the roentgenogram of April 13, 1946, this defect had filled in.

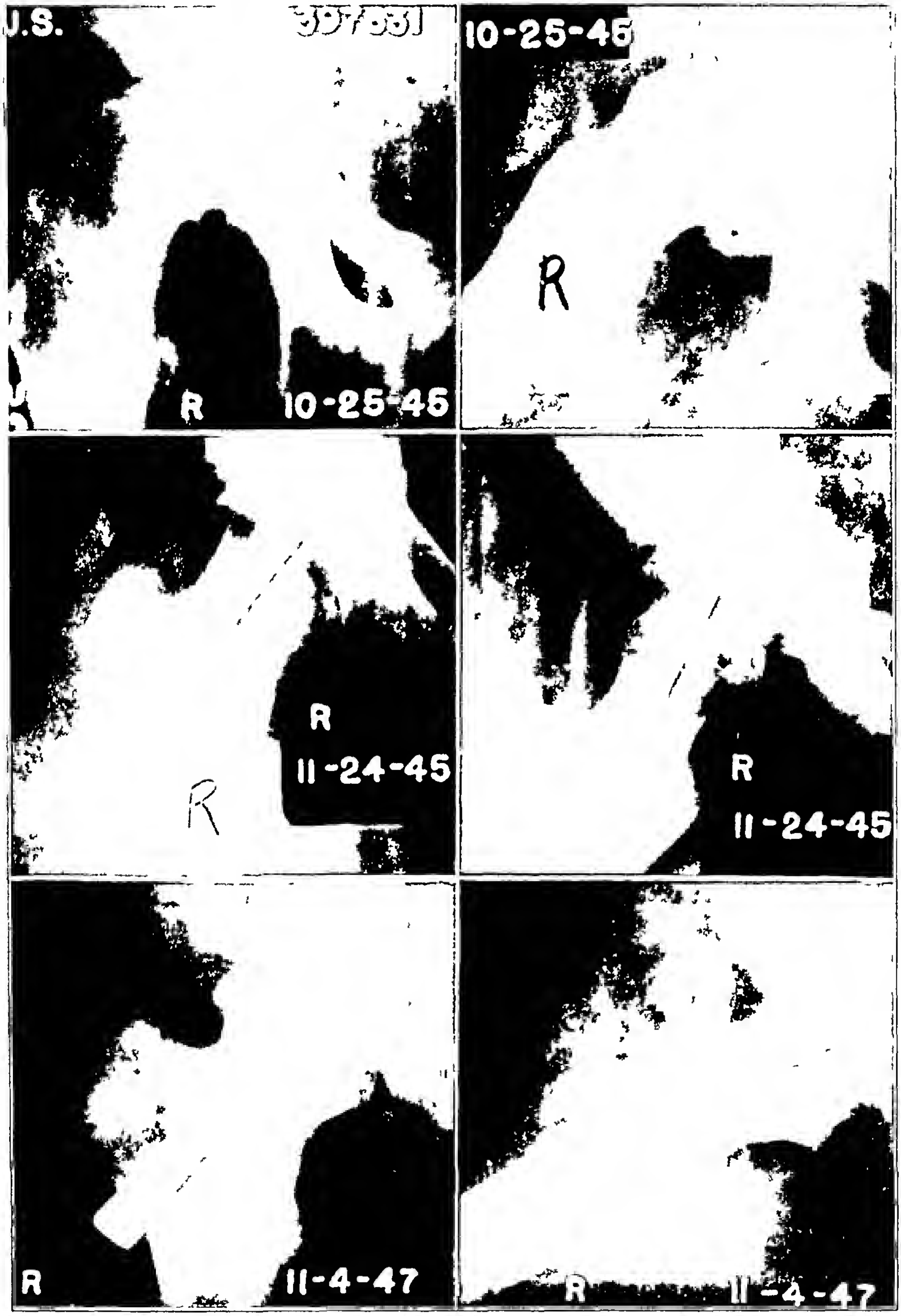

FIG. 3

Nailed after epiphyseal osteotomy.

J. S., a male, aged fifteen years and five months, was operated upon October 30, 1945. In roentgenograms taken November 24, reduction is satisfactory, but there is a large defect between the head and neck from unnecessary excision of part of the neck. On November 4, 1947, the defect had completely filled in.

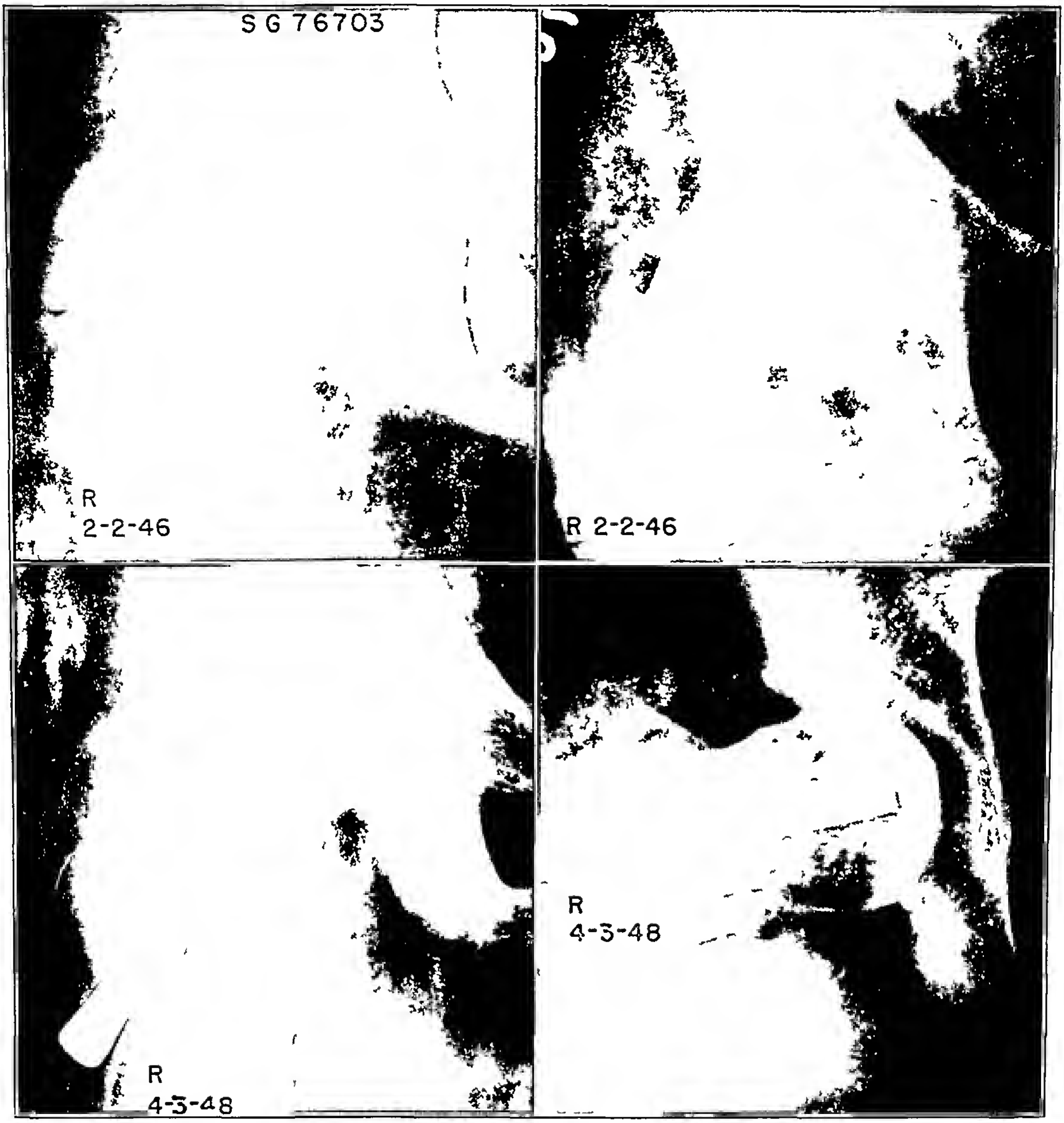

Fig 4

Nailed after epiphyseal osteotomy

S G, a male, aged thirteen years and three months, was operated upon February 16, 1946 The marked slipping present on February 2 is seen to be satisfactorily reduced on April 3, 1948 Localized bone atrophy appears at the lateral superior aspect of the head in the anteroposterior view of April 3

treatment by nailing in fifty-one cases of slipped capital femoral epiphysis A roentgenographic survey of those cases is now presented

The authors reported a study of thirty-one patients, four with bilateral involvement, this represented a total of thirty-five hips, nailed *in situ* because the amount of slipping had been less than one centimeter After an average follow-up period of thirty-two months, the average index of motion was 90 per cent of normal, and the average percentage of normal hip function was 96

Determination of the index of motion, as stated previously by the authors[3], is as follows

"As in our previous report[2], function of the hip was appraised by designating a factor for each motion according to its importance The amount of demonstrable motion is multiplied by this factor to give a product for that particular motion The sum of these products

Fig. 5

Nailed after epiphyseal osteotomy

R. G., a male, aged thirteen years and seven months, was operated upon May 20, 1944. Marked slipping is demonstrable in the roentgenograms of May 13. Follow-up views four years later show good reduction. Localized bone atrophy appeared at the anterior superior aspect of the head following operation.

represents the 'index of motion'.[1] An example of the use of the index of motion in a specific case follows:

	Motion, Degrees	*Factor*	*Product*
Flexion	145	0.4	58
Abduction	45	0.4	18
Adduction	30	0.2	6
Rotation			
Internal	30	0.2	6
External	60	0.1	6
Extension	10	0.1	1
			95

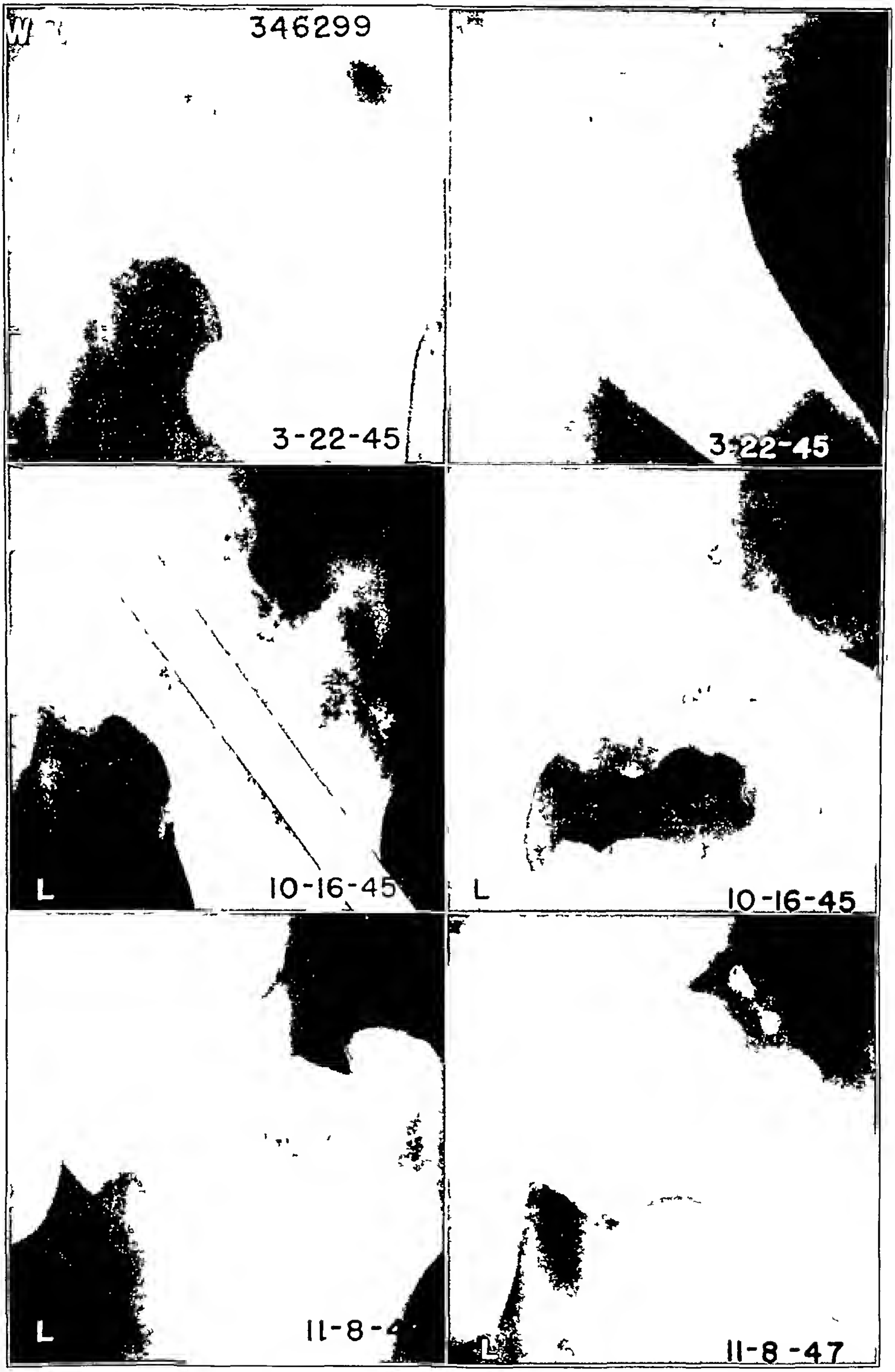

Fig. 6

Nailed after epiphyseal osteotomy

W. R., a male, aged fourteen years and eight months, was operated upon April 7, 1945. There was marked slipping initially, which was reduced satisfactorily. The nail was removed on December 11. Calcification appeared in the anterior capsule following operation.

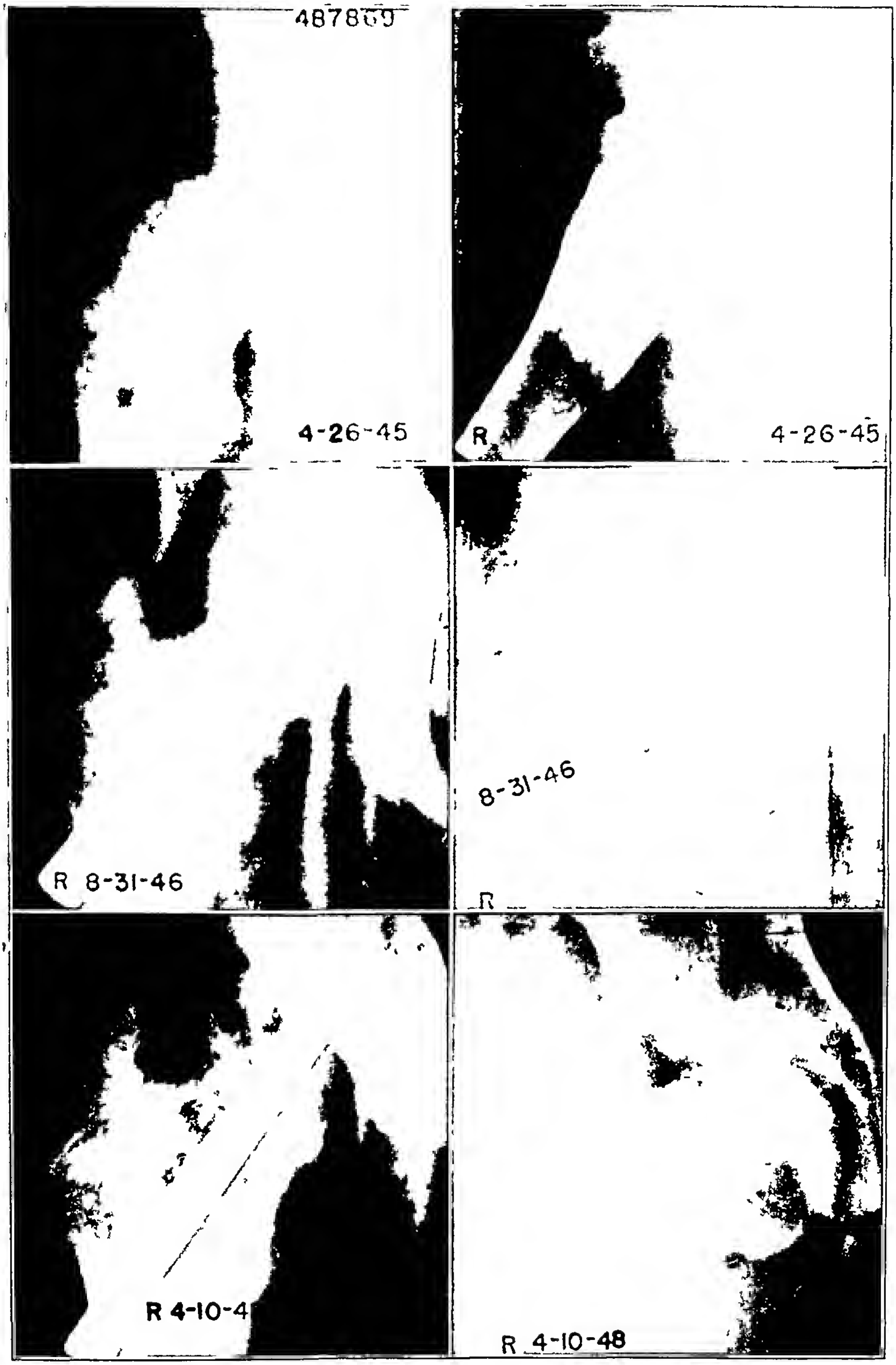

FIG. 7

Nailed after epiphyseal osteotomy

R. P., a male, aged thirteen years and three months, was operated upon May 21, 1945. The initial films, taken April 26, 1945, show marked slipping. On August 31, 1946, following replacement of the head, a prominent defect was visible, both superiorly and inferiorly, at the junction of the femoral head and neck. On April 10, 1948, the defects had largely filled in, with virtual restoration of normal smooth contours.

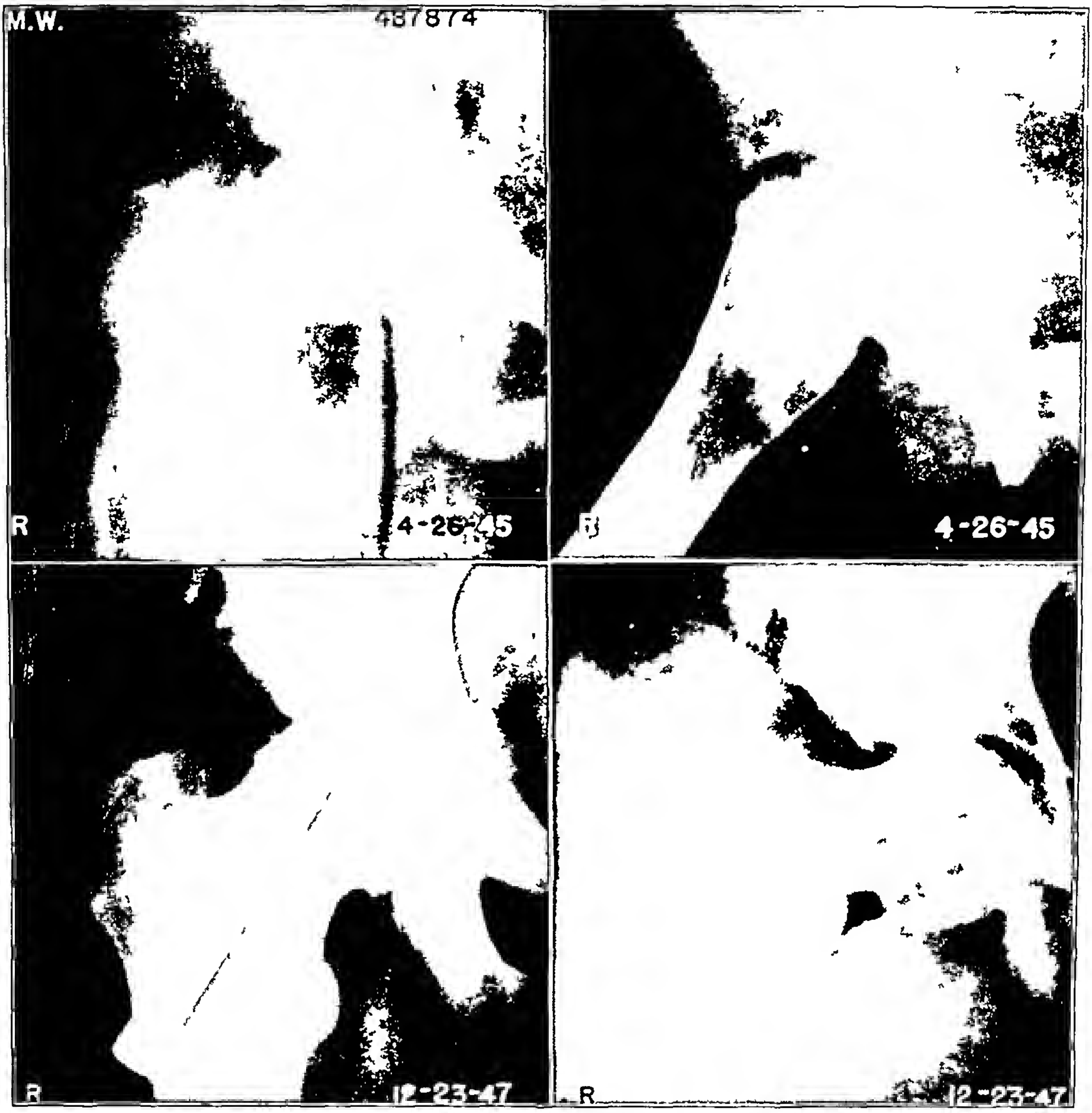

FIG 8

Nailed after epiphyseal osteotomy

M W, a girl, aged twelve years and ten months, was operated upon May 1, 1945 In the roentgenograms taken on April 26, slipping was marked On December 23, 1947, reduction was satisfactory

"On this basis, the index of hip motion was then computed for the affected hip as compared with the sound hip Since such an index of motion does not include pain or limp, we assigned equal value to the index of motion, absence of pain and absence of limp, calling the average of these the percentage of true normal function of the hip"

The roentgenograms taken at the end of a seven-year follow-up period (Fig 1) indicate the results that can be expected from nailing *in situ*, when the minimal amount of slipping is detected early Early mobilization and active weight-bearing on crutches within two or three weeks after operation promote preservation of the physiological function of the hip In this series of cases, in which nailing was done *in situ*, traumatic arthritis or aseptic necrosis of the femoral head has not occurred

Sixteen patients were reported with marked slipping (more than one centimeter) They were treated with arthrotomy, osteotomy through the epiphyseal plate, replacement of the head to its anatomical position in relation to the neck, and lateral nailing for fixation After an average follow-up period of thirty-three and one-quarter months, the average index of motion was 85 per cent of normal, and the average percentage of normal hip

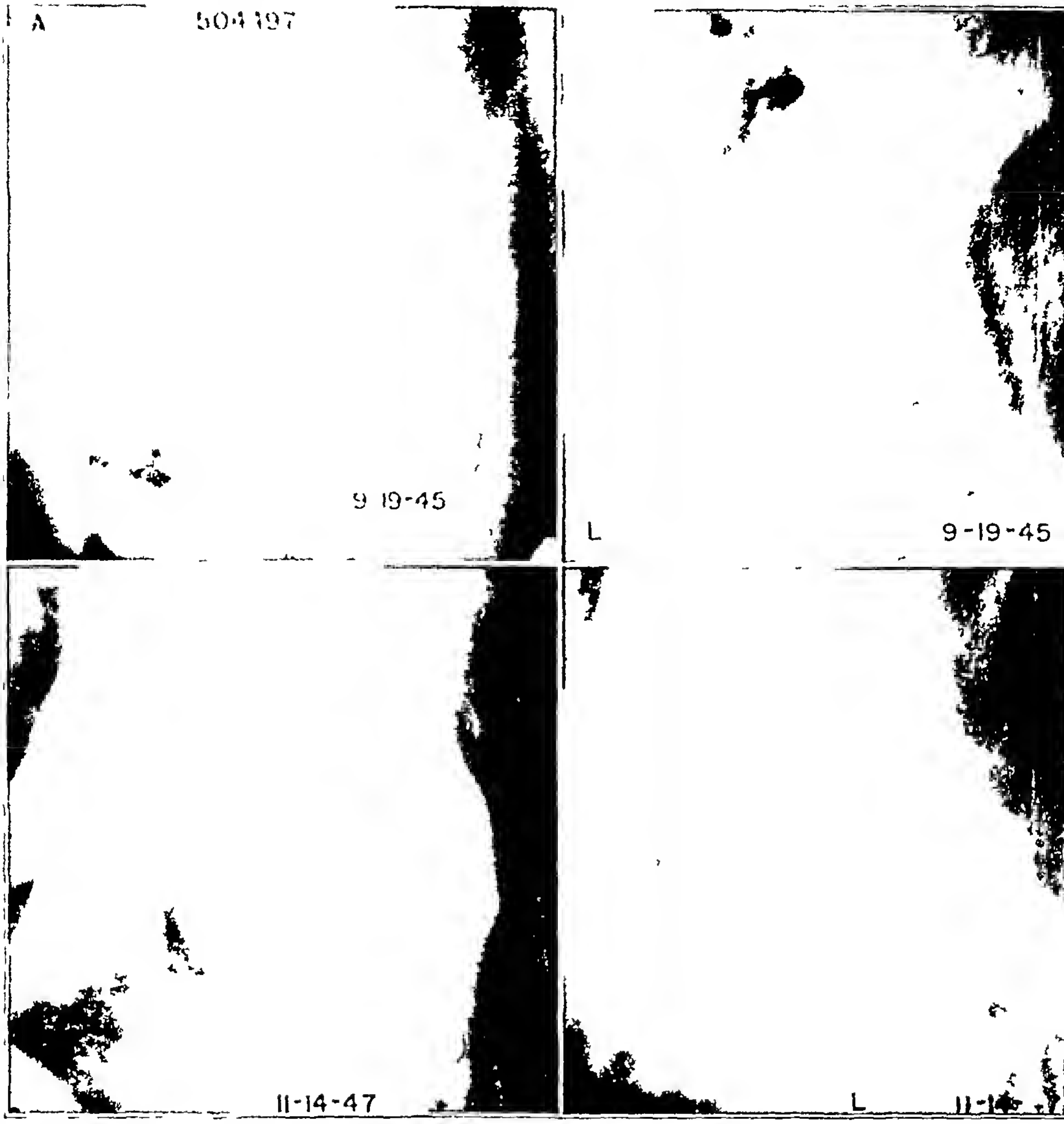

FIG. 2

Nailed after epiphyseal osteotomy.

P. A., a male, aged fourteen years and four months, was operated upon September 24, 1945. Marked slipping was present initially, with good reduction evident in the two-year follow-up. A small circular calcification may be seen in the anterior capsule in the postoperative roentgenograms.

function was 92. Roentgenograms (Fig. 2) depict the results obtained by a restoration of the physiological function of the hip, achieved through replacement of the disrupted parts and early postoperative mobilization.

The condition of a male, aged fifteen, who had had an open reduction and nailing of his right hip, is illustrated in Figure 3. The postoperative roentgenograms, taken on November 21, 1945, show that a portion of the neck at the epiphyseal plate had been osteotomized. This procedure was carried out in the hope of simplifying replacement of the head. Excision of this portion of the neck, however, made realignment of the head more difficult, because of the loss of an important landmark to guide replacement. After replacement, a large defect in the neck is obvious at the site of osteotomy. Fortunately, in this case the defect filled in, as shown in the lower section of Figure 3, which consists of roentgenograms taken two years later. This patient's hip eventually attained an index of motion of 88 and a percentage of function of 95.

mediate postoperative active mobilization of the restored hip Adherence to these fundamentals minimizes the possibility of aseptic necrosis of the femoral head, either alone or in association with traumatic arthritis

In this series, traumatic arthritis has been encountered in only two cases, as follows

J A, a male, aged fifteen, had a marked amount of slipping, as shown in Figure 15, upper views The condition was treated by arthrotomy with satisfactory reduction, but with improper placement of the nail for fixation Four years later, there was obvious traumatic arthritis, probably due to the anterior projection of the nail through the head

C J, a boy, aged eleven, was treated by open reduction and nailing of the left hip, in July 1933 (Unfortunately, the early roentgenograms were destroyed) Reduction was incomplete A plaster spica was applied eighteen days after operation and was kept on for three months The nail was removed six months later The anteroposterior view in 1940, seven years after operation (Fig 16), shows that the head of the left femur was irregular and that the neck was shortened and broadened There were several rarefied areas in the head and neck In the two center views, thirteen years after operation, the rarefied zones appeared to have filled in partially with new bone In the last eight-year period of observation, as shown in the roentgenograms (Fig 16, lower views), the anticipated progression in the degree of arthritic change has not occurred This patient obtained a rather satisfactory functional result, despite two errors in treatment,—namely, apparent inaccurate reposition of the head on the neck and unnecessary immobilization in a plaster spica

The authors believe that if the slipped capital femoral epiphysis is treated by nailing, either *in situ* or after open reduction with replacement at the epiphyseal plate, depending upon the degree of slipping, the danger of further

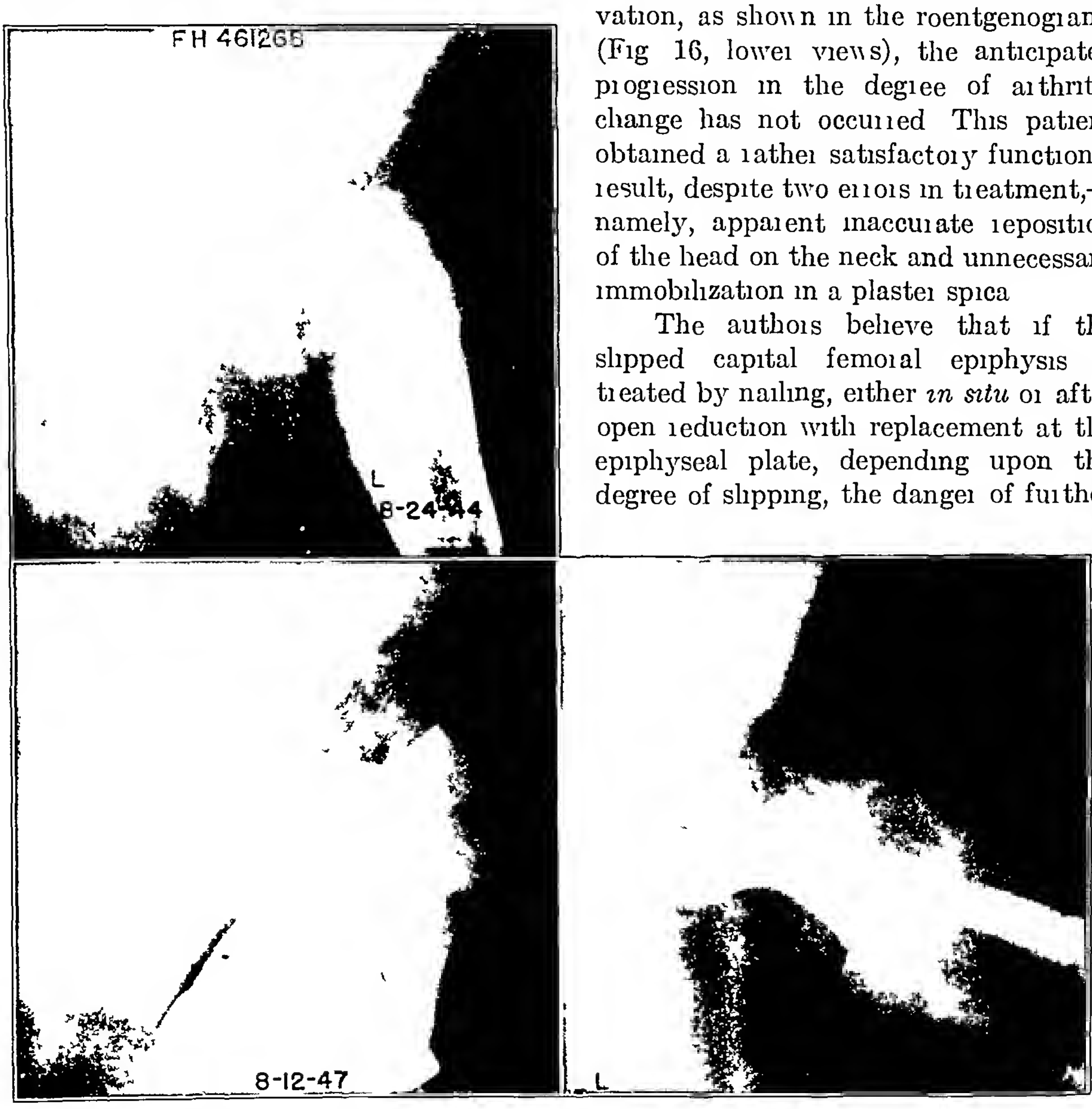

Fig 12

Nailed after epiphyseal osteotomy

F H, a male, aged thirteen years and nine months, was operated upon September 8, 1944 Extreme slipping was present on August 24 Three years later there had been virtual anatomical restoration

slipping is eliminated. Furthermore, the patient can be returned to his normal environment within two or three weeks, walking with crutches, and within two months he is able to walk without extrinsic support.

The authors have noted roentgenographic evidence of fusion of the epiphysis within four to eight months after nailing in the open-reduction cases and within six to eighteen months in the cases nailed *in situ*. In the latter group, the nailed epiphysis fused eight to twenty-one months sooner than that on the uninvolved side. With open reduction, the nailed epiphysis fused five to thirty-five months before that on the uninvolved side. Apparently, osteotomy through the epiphyseal plate accelerates fusion more rapidly than fixation by nailing *in situ*.

The nail should not only cross the epiphyseal plate, but should extend well into the head. In four cases nailed *in situ*, growth continued away from the end of the nail (Figs. 17, 18, and 19). None of these patients had any complaints, and no further slipping or shortening resulted.

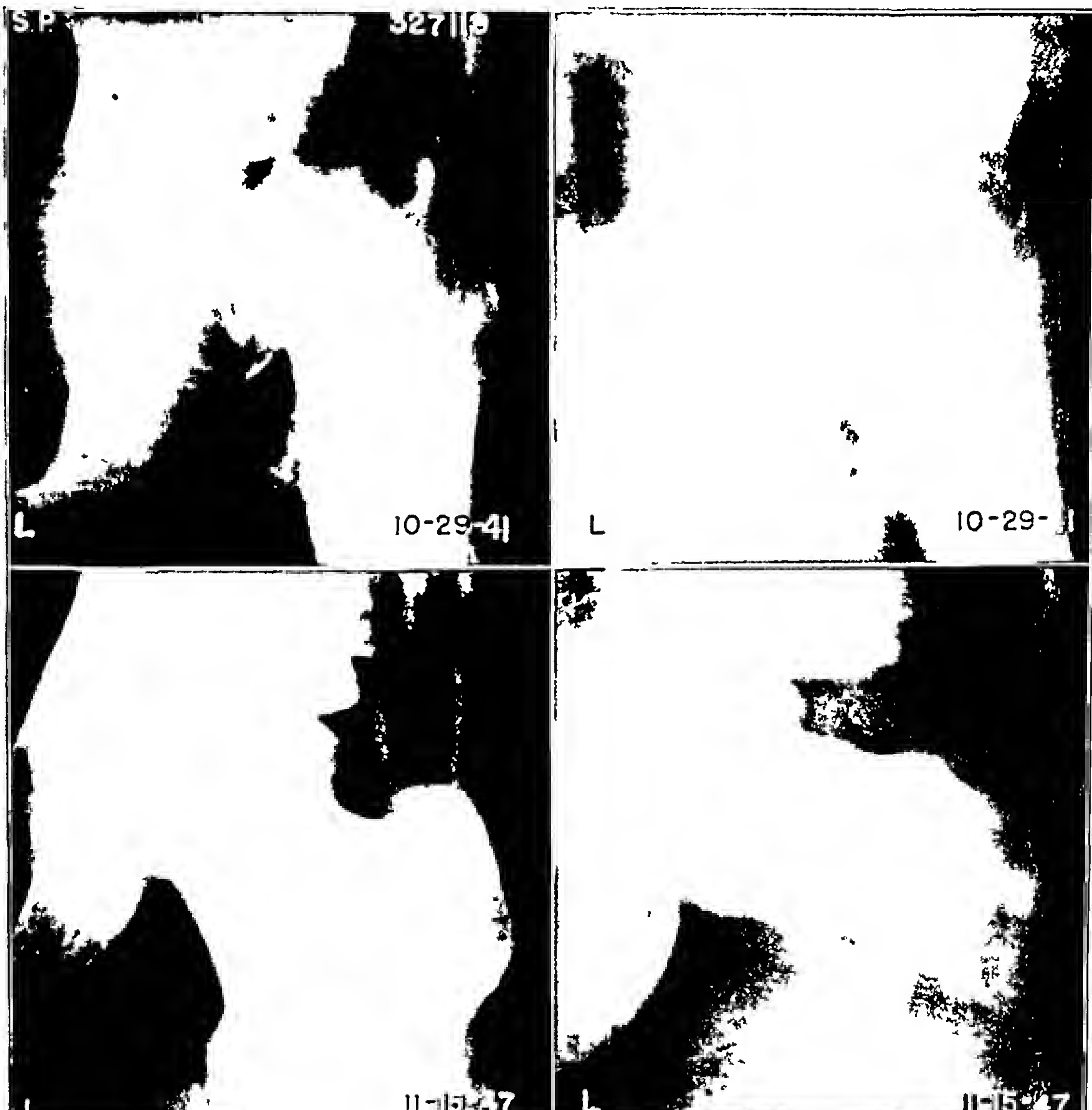

Fig. 13

Nailed after epiphyseal osteotomy

S. P., a male, aged fourteen years and seven months, was operated upon October 31, 1941. Severe slipping, demonstrable in the roentgenograms of October 29, 1941, had been satisfactorily reduced, as shown in the six-year follow-up views.

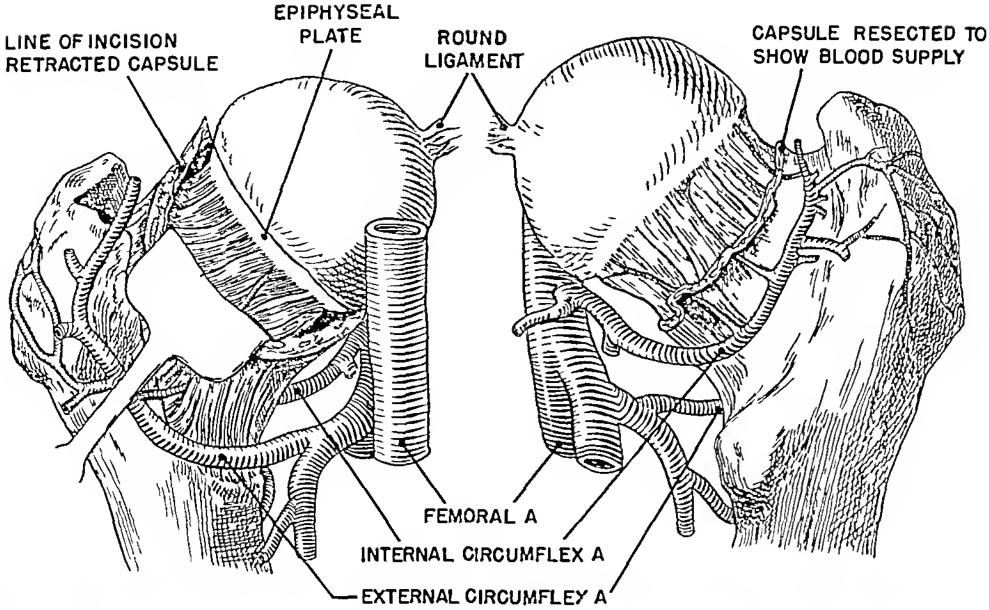

Fig 14

Schematic drawing showing blood supply to the femoral head and neck

Fig 15

Nailed after epiphyseal osteotomy

(*Continued on page 15*)

Fig. 15 (*Continued*). J. A., a male, aged fifteen years and three months, was operated upon May 1, 1944. Marked slipping, present on April 1, 1944, had been reduced by January 15, 1948. Here the nail, shown in the anteroposterior view to be apparently well placed, in the lateral view projects through the anterior cortex of the head. There is considerable irregularity of the articular margin of the head and, to a lesser degree, of the acetabulum. Faulty placement of the nail apparently is the major factor in the production of the traumatic arthritis.

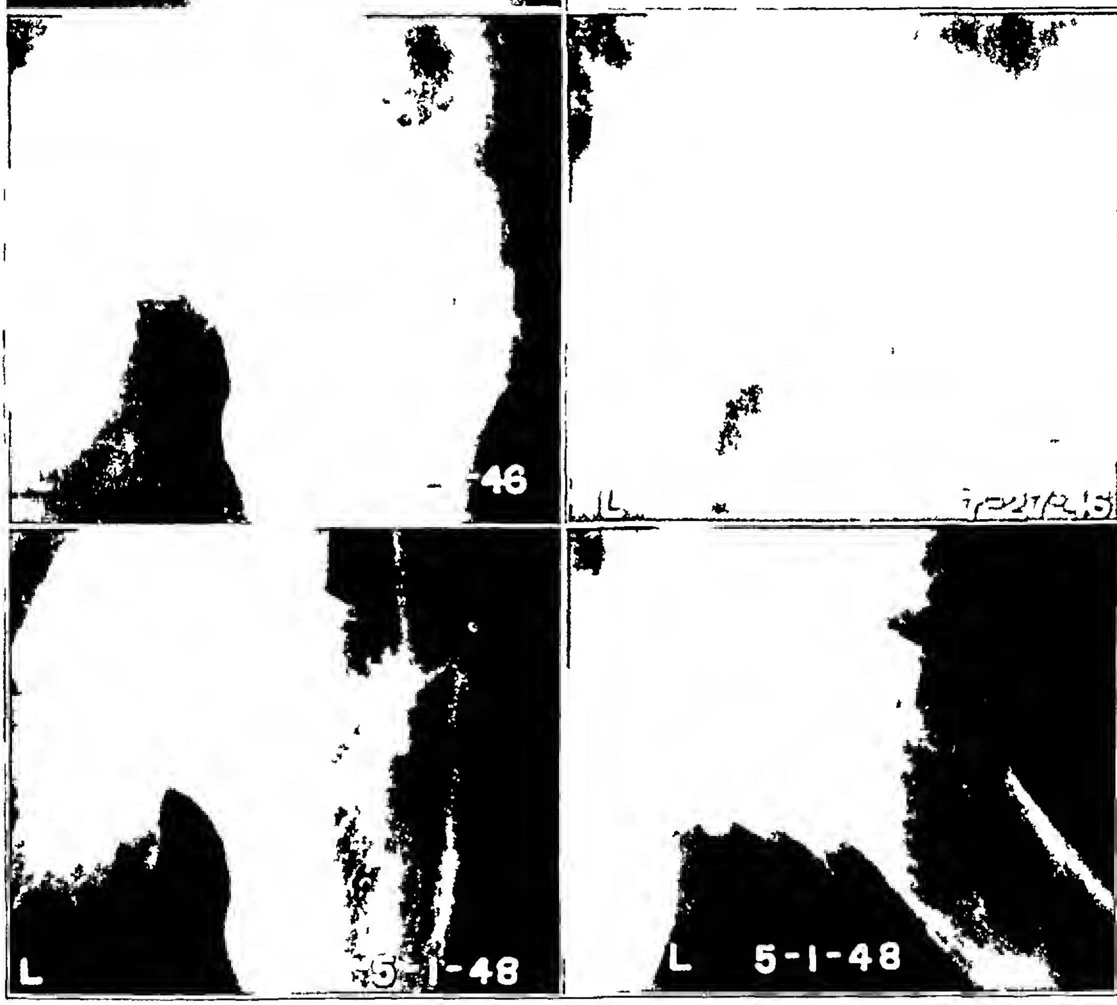

Fig. 16

Nailed after epiphyseal osteotomy

C. J., a male, aged eleven years and seven months, was operated upon July 7, 1933. (The early roentgenograms were destroyed.) The nail was removed six months after operation. The anteroposterior view on October 27, 1940, showed shortening and broadening of the femoral neck and deformity of the femoral head with irregularity of the articular margin, indicative of traumatic arthritis. In the reproduced films taken at the end of the last eight-year period of observation, no obvious progression of the traumatic arthritis was evident.

In two cases there was slipping of the upper femoral epiphysis of more than one centimeter, but nailing was carried out *in situ* (Figs. 20 and 21). Although these patients now

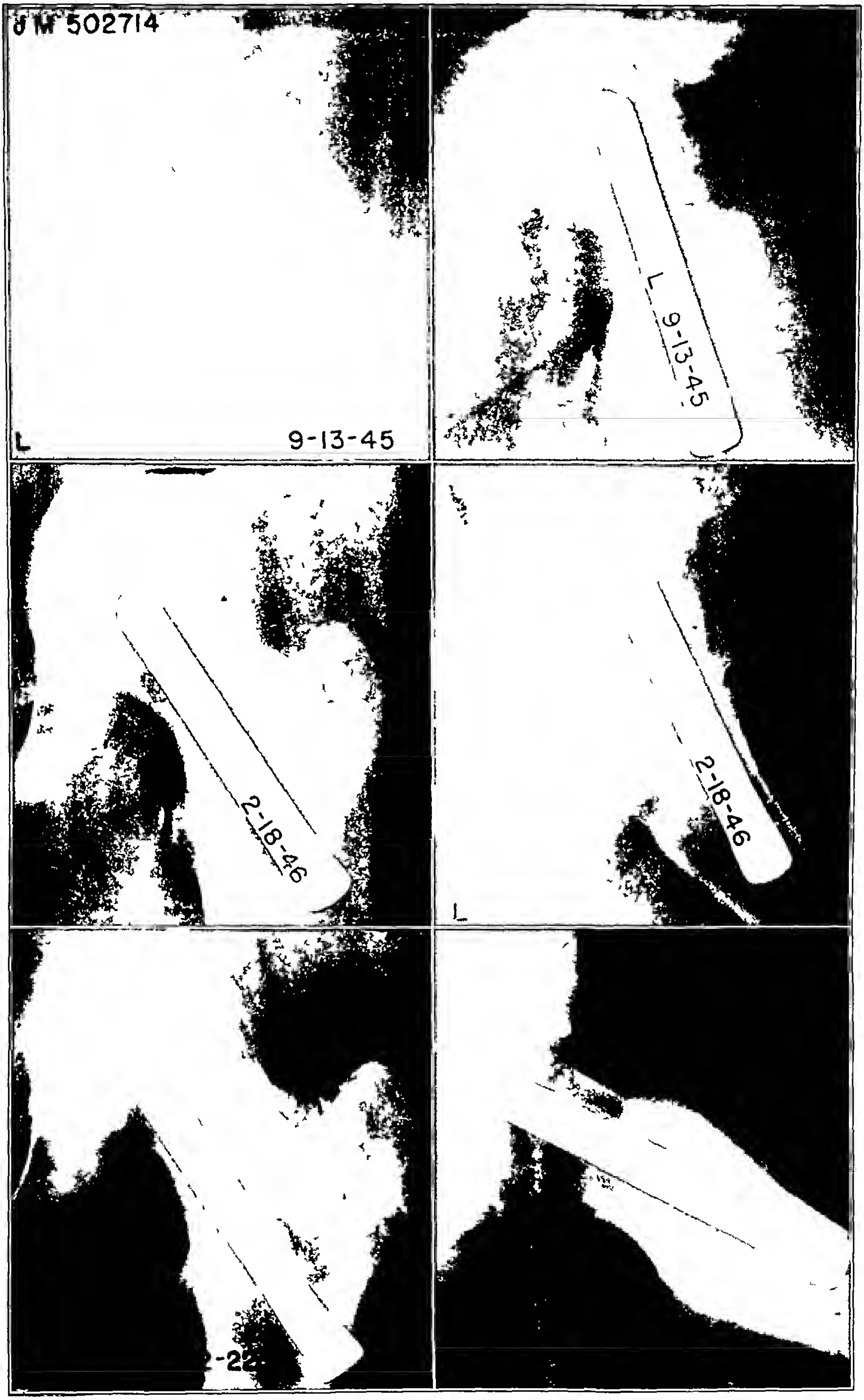

FIG 17
Nailed *in situ*

(*Continued on page 17*)

Fig. 17 (*Continued*)

E. M., a girl, aged eleven years and nine months, was operated upon September 6, 1945. In the serial anteroposterior and lateral roentgenograms, covering a period of twenty-seven months, a progressive change occurred in the relative position of the nail to the epiphyseal plate. This indicates that epiphyseal growth was not arrested by the nailing procedure. No further slipping occurred. The central part of the epiphyseal plate showed fusion in the films of December 22, 1947.

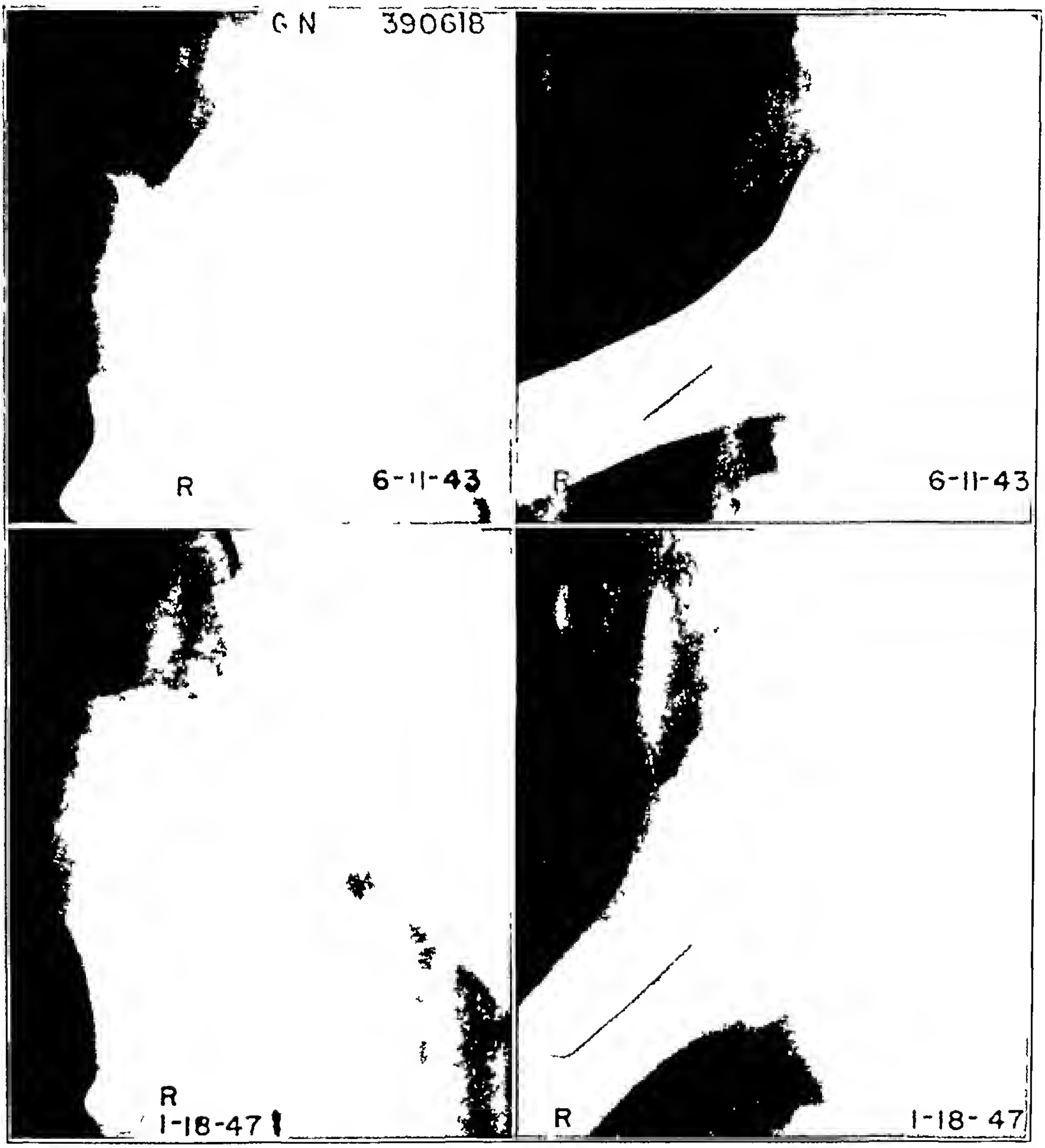

Fig. 18

Nailed *in situ*

G. N., a male, aged twelve years and eight months, was operated upon February 5, 1943. Nail is shown, in films of June 11, 1943, to be correctly placed. Epiphyseal growth continued. The four-year follow-up views show the nail completely distal to the epiphyseal plate. No further slipping occurred.

have excellent function, an open reduction with replacement of the head to a more valgus position on the femoral neck might have prevented the obvious residual deformities which may very well be the precursor of traumatic arthritis.

SUMMARY

Roentgenograms have been presented to illustrate

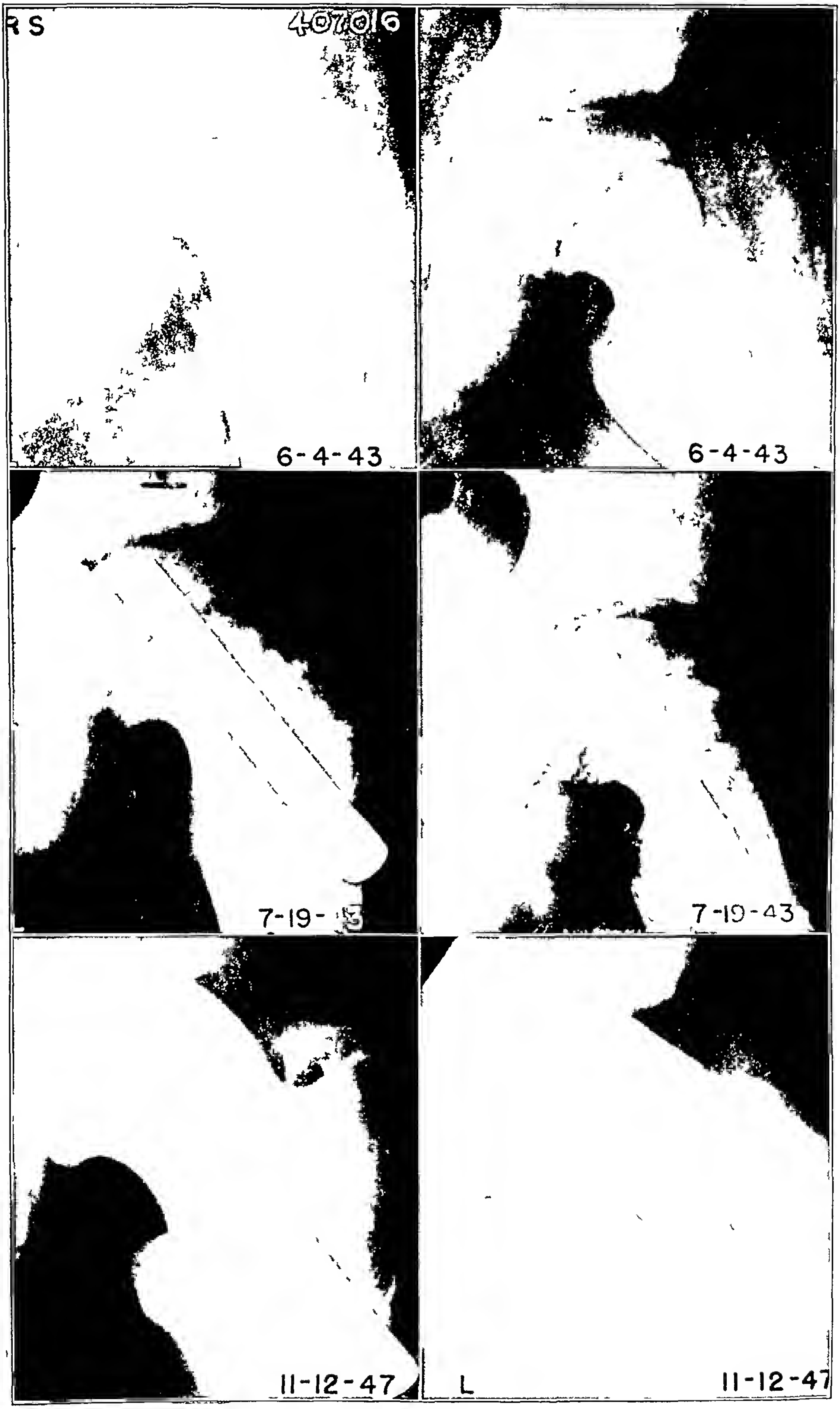

Fig 19

Fig. 19

Nailed in situ

[illegible] months, was operated upon June 7, 1943. Growth [illegible] plate following [illegible] nail [illegible] roentgeno[illegible] July [illegible] 194[illegible]. By November 12, 1947, the nail was completely distal to the [illegible]

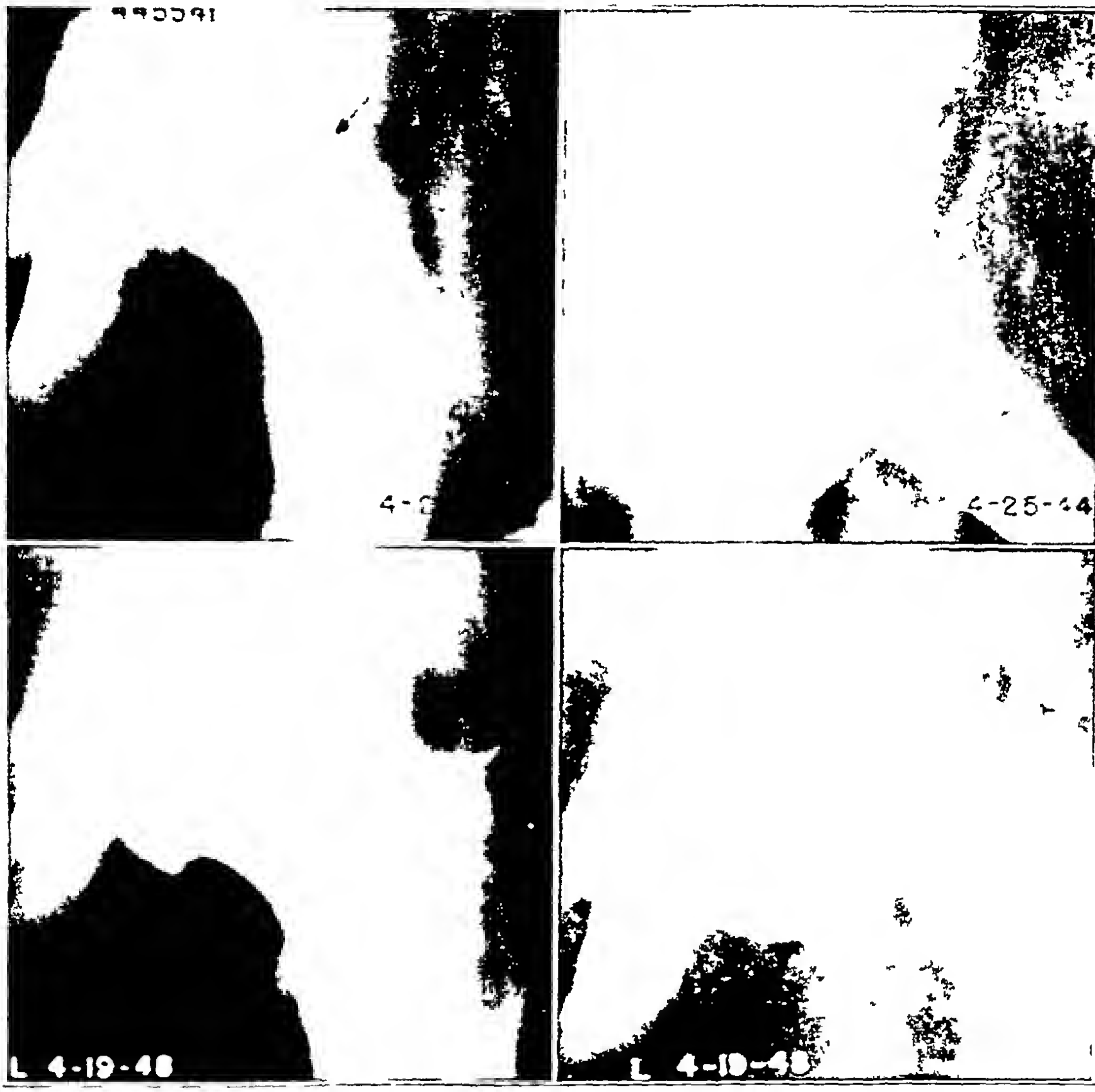

Fig. 20

Nailed in situ

[illegible] R., a male aged thirteen years and two months, was operated upon May 6, 1944. On April 25, the slipping was approximately 1.5 centimeters. Arthrotomy, osteotomy at the epiphyseal plate, and replacement before nailing would have prevented the residual deformity at the anterior superior junction of the head and neck, as seen in the follow-up views. The nail was removed twenty months after operation.

1. The results of the treatment of slipped capital femoral epiphysis by nailing *in situ* and by nailing after osteotomy and replacement.

2. The prevention of further slipping, acceleration of fusion of the epiphysis, and preservation of a relatively normal anatomy of the hip accomplished by this method.

3. The absence of the accelerated fusion in four cases in which growth persisted until the epiphyseal plate had advanced beyond the end of the nail.

The results of this method of treatment suggest that adequate replacement with a

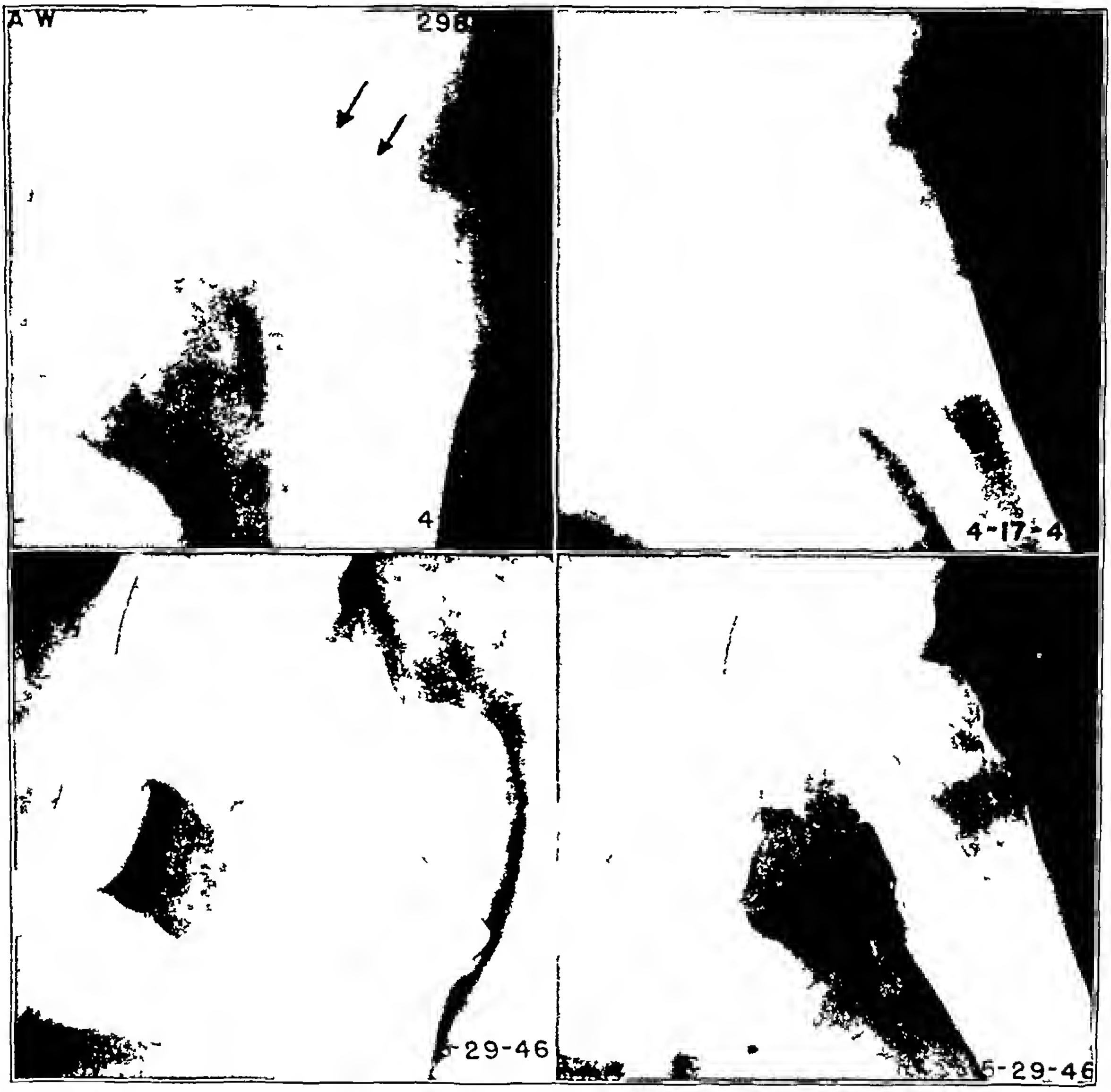

Fig 21

Nailed *in situ*

A W, Jr, a male, aged thirteen years and four months, was operated upon April 28, 1941 Initial anteroposterior and lateral views, taken on April 17, 1941, showed slipping of approximately 1 5 centimeters By our present standards, this patient should have been treated by arthrotomy, osteotomy at the epiphyseal plate, and replacement before nailing This would have prevented the prominent bony projection at the superior junction of the head and neck, obvious in the films of May 29, 1946

minimal amount of circulatory embarrassment to the femoral head and neck, followed by early mobilization and weight-bearing with the aid of crutches, is of paramount importance

Treatment of the slipping while it is minimal permits a simpler operative procedure with an excellent prognosis, and eliminates the hazards and the inferior results stemming from the difficult procedure which is indicated after the slipping has become marked

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DISCUSSION

NOTE: The Discussion concerns a group of papers on the treatment of slipped epiphysis, presented at the same session. The other three were:

"The Management of Incipient Epiphyseolisthesis of the Hip" by Samuel Kleinberg, M.D., New York, N. Y.

"Slipping of the Upper Femoral Epiphysis" by Beckett Howorth, M.D., New York, N. Y.

"Treatment of Slipping of the Upper Femoral Epiphysis: A Study of the Late Results in Forty-two Cases" by Clarence H. Heyman, M.D., Cleveland, Ohio.

DR. PHILIP D. WILSON, NEW YORK, N. Y.: There is nothing new about the etiology of this condition. The endocrine factor is still discussed, but no clear evidence has been produced to show that it plays any part. It is true that many of the patients are overweight and that they often show signs of endocrine dysfunction, but I think we may conclude that the extra weight is the chief factor, because it overloads the epiphyses. There is no evidence that treatment along endocrinological lines will make any difference. As a matter of fact, if these patients are treated by various types of sex hormones, the effects upon the precocious development of the secondary sexual characteristics, as well as the accompanying changes, are often so troublesome that it seems to me the orthopaedic treatment is preferable and far more certain. The average age of these patients, as stated by the authors, is the same as I found in a previous study: thirteen and one-half years for the boys and eleven and one-half years for the girls. I think that this has no bearing on the possible endocrine relationship, as it is well known that the growth rate in girls is more rapid and that their epiphyses mature at an earlier age than in boys.

I believe that nothing new has been shown in relation to the pathological changes that occur with epiphyseal displacement.

As far as treatment is concerned, I think we are all agreed upon the need for early recognition and diagnosis of these cases before displacement of any extent has taken place. Most of these patients are first seen by the family physician, and the only way we can help is by improving medical education. We know of the increasing demands that are being made upon the medical schools to include additional material in their curricula. It seems to me that one criterion which might be applied is whether or not the teaching is of fundamental importance, and that when early diagnosis and treatment are so important and make such a difference in the final result in slipping of the upper femoral epiphysis, it should be stressed to the medical student in such a way that he will never forget to look for it. Speaking as a representative of the City of New York, I am glad to say that there has been a great improvement in the early diagnosis and recognition of these cases. Our experience over the last ten years shows that at least two-thirds of these cases are seen in hospital clinics when slipping is minimal, and we feel that it is not necessary to correct the deformity. We treat these cases as emergencies and have them admitted to the hospital immediately, where fixation of the epiphysis is carried out with a Smith-Petersen nail. We send them home from the hospital in about two weeks, walking with crutches and with an elevation under the shoe on the uninvolved extremity.

As far as manipulative reduction of the deformity is concerned, the only advocate for this method among the speakers is Dr. Heyman, who reports good clinical results in seventeen of twenty-one patients, but good roentgenographic improvement only in fourteen. He thinks that the fixed external rotation and limitation of abduction are often due to contracture of the muscles and ligaments, rather than to bone deformity. I'm sure we would all agree with him that muscle contracture and spasm play a part in limiting the motion, but I think that this is not true when the roentgenogram shows bone deformity. In old healed cases with displacement we find similar limitation, and that is undoubtedly due to the bony obstruction. He finds this is true also in these cases, because these are the ones in which he has removed surgically the bony obstruction to motion.

A great many of the older surgeons in the audience were brought up on the manipulative treatment of slipped femoral epiphysis, followed by immobilization in a plaster spica; most of them have abandoned this treatment, and we should ask why. Speaking as an individual, my own experience has convinced me that I often fooled myself and thought I had accomplished reduction when such was not the case. Waldenström explained this by showing a specimen he had recovered from a child with slipping epiphysis, who had been subjected to manipulation and fixation in plaster. The roentgenogram seemed to show reduction, but when the child died of some extraneous condition and the specimen was recovered, he found that the deformity was the same as it had been originally. Also, in some of my cases, avascular necrosis of the epiphysis developed after manipulation, and I was convinced that my efforts to obtain wide abduction and internal rotation had injured the vessel-bearing tissue of the capsule to such an extent that necrosis resulted. Furthermore, I believe too much consideration should not be given to the results, unless these cases have been followed for many years. From experience with older cases in which osteo-arthritis has developed, we can see that the patients apparently did well for a number of years following their treatment before they began to complain of pain, and yet by roentgenographic study we see that they have had gross deformity of the femoral neck all the time.

The other speakers have advocated various methods to secure internal fixation of the epiphysis and early healing. There are those who favor the Smith-Petersen nail, others use various types of pins, and Dr. Howorth and his associates have employed small bone grafts, driven up into the head through drill holes. I do not suppose we are ever going to reconcile our differences with regard to technique, nor do I believe that it is

really important, because all of us are aiming to accomplish the same thing by different methods,—namely, fixation of the epiphysis and early mobilization I am perfectly willing to accept Dr Howorth's operation, but it seems to me that the nail accomplishes the same thing, more simply and with less risk If the epiphysis is properly fixed through the femoral neck, it will heal as rapidly with the nail as with the graft, and less harm is done to the bony structure I have seen bad results from nailing, but because the operation had been done improperly There is need for a good technique in introducing and placing the nail accurately This is a matter that calls for teamwork between the surgeon and the roentgenologist, but I am sure that it can be done

We have used, at the Hospital for Special Surgery, about the same after-treatment as Dr Kleinberg has described We have a series of over seventy cases with minimal deformity that had been treated by simple nailing There was one case with avascular necrosis, but this was due to the fact that the epiphysis had been driven away from the neck when the nail was introduced I think that can be avoided if one studies the roentgenograms carefully When one notes a wide separation of the epiphysis from the neck and an appearance of considerable instability, then one should introduce a guide pin to fix the epiphysis and employ a cannulated nail, or one can use a lag screw We had one case of infection with a bad result I would stress the need for avoidance of unnecessary damage to the bone structure in introducing the nail If one drives the nail in and takes it out and repeats this performance several times, there is great damage to the internal cancellous structure of the neck, and it may have an effect upon the blood supply to the epiphysis I quite agree with Dr Heyman that this is not desirable and that it affects the result

We must now consider what to do in the cases with deformity and displacement Should we attempt open reduction by epiphyseal osteotomy or by transcervical osteotomy? Of course, in an early case we may employ traction, but I am assuming that we are discussing cases in which the epiphysis is united, with resulting deformity I believe that open reduction is indicated only in the acute cases in which the epiphysis is widely displaced and reduction is not obtained by traction In 1927, I reported a group of cases with displacement in which I had separated the epiphysis from its deformed position, replaced it on the neck, and fastened it with a nail The results in these cases were good but later, when I did more of them, I began to encounter avascular necrosis of the epiphysis and I gave up the method I then favored accepting the intra-articular deformity and correcting the position of the limb by a subtrochanteric osteotomy Later, however, at the Hospital for Special Surgery, I observed the cases in which Dr Lewis Clark Wagner had corrected the deformity by cervical osteotomy, and he convinced me that this is a very good procedure and that the results are satisfactory Dr Carl Badgley has also reported good results from this method

There is one point that I consider important in the operative approach to these hips,—namely, that the reflection of the capsule from the base of the neck impairs the blood supply to the epiphysis, and therefore should be avoided With a transverse incision close to the anterior rim of the acetabulum, there is less danger of causing damage to the blood supply

Many surgeons have noted the development of arthritis in the hips of patients with epiphyseal displacement following operations to correct the deformity In such cases there is no actual necrosis of the epiphysis or absorption of it, but the joint cartilage space becomes narrowed and the hip becomes fixed I have performed arthroplasty in some of these cases later, and this has given me the opportunity of examining the head under microscopic section I am convinced that the loss of the joint cartilage is the result of a limited or partial avascular necrosis, which is followed by revascularization in the subchondral area of the bone This has been shown beautifully in some of the sections

Dr J Albert Key, St Louis, Missouri I became interested in slipping of the upper femoral epiphysis in 1920 and studied the cases at the Massachusetts General Hospital That study was published in 1926 The pathological changes in the bone had been well worked out before 1900 Sprengel and other German surgeons had noted the changes in the epiphyseal line, shortening of the femur, and displacement of the head that are now being described to us I think that the changes in the synovial membrane have not been noted before

In none of the cases that we treated by manipulation could any reduction of the deformity be demonstrated in other words, we were working on a cap that was firmly fixed to the neck, and all we did by manipulation was to traumatize the articular surface Dr Carl Badgley later opened some of these hips, after unsuccessful manipulation, and saw evidence of injury to the cartilage

I am at a total loss to explain the good results by manipulation, except by the fact that this is a condition of adolescence in which bad results are not evident until middle life The fact that these individuals do not have pain or disability a few years afterward means nothing On the other hand, if these hips were examined carefully, limitation of motion and incongruity of the joint surfaces would probably still be found, and where there is incongruity of the joint surfaces in the hip, arthritis will develop after the individual uses that hip for a number of years

I believe that neither drilling, as Dr Kleinberg did, nor nailing, nor the use of three bone pegs or one bone peg across the center of the epiphyseal line can be depended upon to fuse the epiphysis Dr Phemister, in his operation for stopping bone growth, went to a great deal of trouble not only to curette the center of

(Continued on page 54)

DELAYED AUTOGENOUS BONE GRAFT IN THE TREATMENT OF CONGENITAL PSEUDARTHROSIS*

BY JOHN ROYAL MOORE, M.D., PHILADELPHIA, PENNSYLVANIA

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The etiology of congenital pseudarthrosis still remains obscure, in spite of the diligent work of numerous investigators here and abroad during the past century. Among various etiological hypotheses proposed are: trauma to the foetus, exogenous and endogenous, osseous disease of the skeleton, intra-uterine rickets, osteomalacia, chondromalacia, and osteitis; disease of the amnion, adhesion amnion, amniotic bridle (amniotic-band adhesion), Simonart's ligaments (amniotic bands), and amniotic compression; vascular dysplasia [3, 11], osteopathy due to lesions of the central nervous system, arrest of development and mesenchymal hypoplasia [11], neoplasm and neurofibroma [1]. Tillier in 1928, Ducroquet in 1937, Barber in 1939, and B. H. Moore in 1940 pointed to the frequency with which mollusca, neurofibroma, and café-au-lait spots are found in association with congenital pseudarthrosis and other congenital anomalies. Congenital pseudarthrosis is rare in comparison with other congenital anomalies. Camurati noted twenty-seven cases at the *Istituto Rizzoli* in thirty-two years. The principal site of election is the lower third of the tibia or fibula (slightly more often on the left side than on the right), but the condition has been encountered in other bones of enchondral origin, including the clavicle, humerus, ulna, first rib, and femur. Heredity has been reported a factor in two cases [9]. The lesion is slightly more frequent in the male (57 per cent.) than in the female (43 per cent.).

These statistics and part of the historical data cited were obtained from a study by Mario Camurati of 118 cases collected from the literature or observed at the *Istituto Rizzoli*, reported in 1930.

The histopathological characteristics of the lesion have been generally accepted as conforming to those of acquired pseudarthrosis. Inert, sclerosed, pointed, atrophic bone ends (having the appearance of sucked candy), surrounded by a sleeve of dense connective tissue and developing ultimately the characteristics of a nearthrosis including the cartilage and joint cavity, are the principal findings in the mobile type. Green and Rudo, in 1943, reported the finding of a neurofibroma at the site of a congenital pseudarthrosis of the tibia. This startling discovery did much toward awakening interest in the pathology and etiology of this disease, but to date there has been little confirmation in the literature.

The early treatment of congenital pseudarthrosis included the use of setons by Physick in 1820, as described by Key, injection of such irritating substances as iodine, injection of whole blood, ignipuncture, splints, continuous traction, amputation, and braces. Reichel, in 1902, raised a pedicle graft from the opposite tibia (graft and periosteum were attached to the overlying subcutaneous tissue and skin), crossed the legs, and attached the free surfaces of the pedicle to the exposed pseudarthrosis site by periosteum and skin. The skin and subcutaneous tissue of the flap were returned to the original bed in twenty days. Success was reported. This method was adopted for a time by Codivilla, Coenen, and Nové-Josserand. Codivilla later (in 1906) employed long, narrow osteoperiosteal grafts in barrel-stave fashion. Tillier, in a report in 1928, cited several successes with the Curtillet method and recommended arterial sympathectomy in instances of slow consolidation. Froelich, in 1910, recommended massive osteoperiosteal grafts.

The history from 1910 until the present period records the continuation of surgical

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 26, 1948.

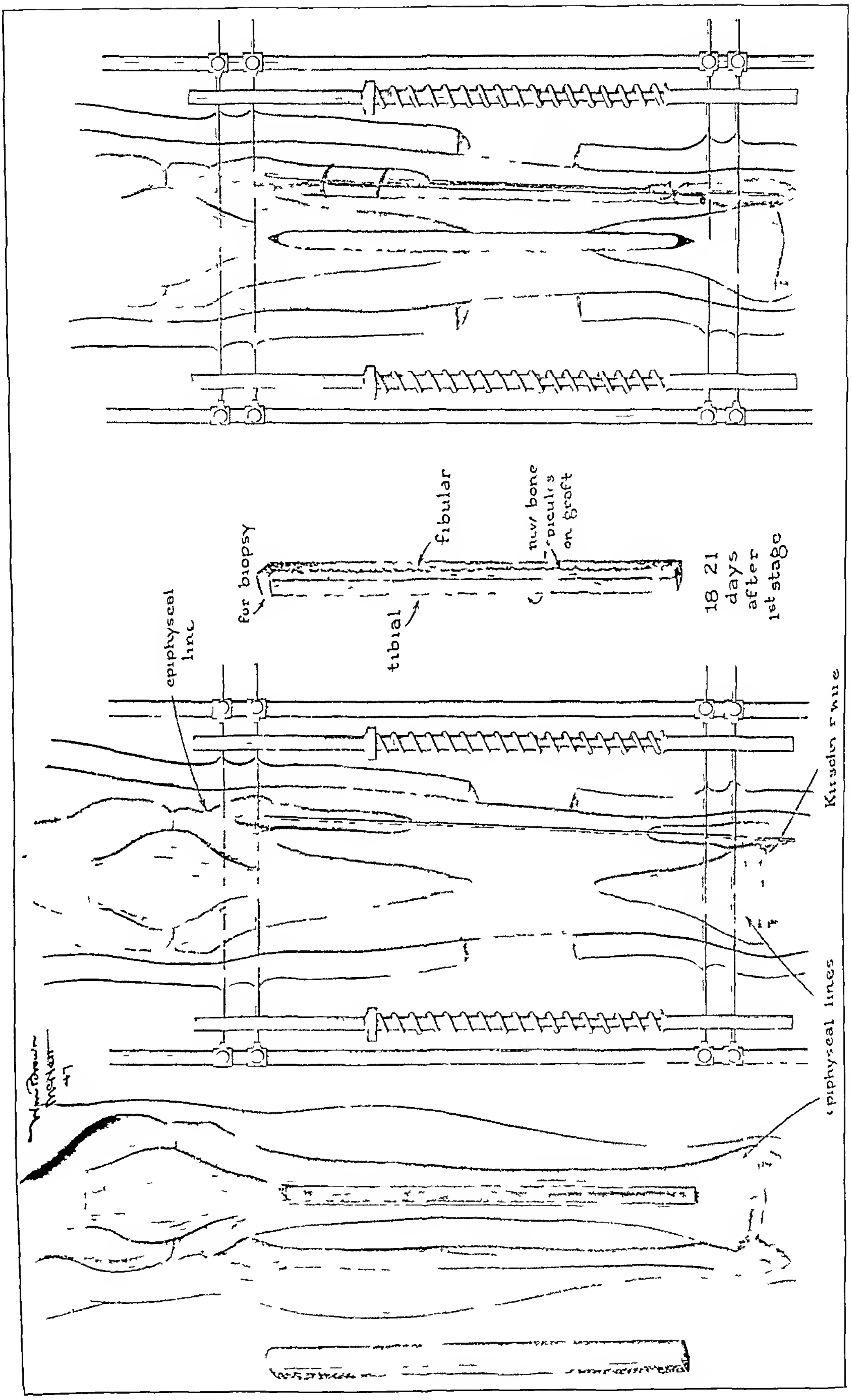

FIG 1

Schematic drawing of the first and second stages of the delayed graft Shows the employment of the lengthening apparatus and plaster used in primary fixation

osteosynthesis is the principal method of treatment of congenital pseudarthrosis,—the inlay graft of Albee, the massive onlay graft of Campbell, Henderson, Gill, and others, the plated osteoperiosteal graft of McBride, multiple chip grafts[17], whole fibular transplantation proposed by Hahn[8, 20], and side-to-side tibiofibular synostosis. Orell, in 1937, contributed three types of heterogenous and homogenous grafts,—namely, os purum, os novum, and boiled bone. In 1941, Boyd reported the dual onlay graft (homogenous). Boyd excised the connective tissue forming the pseudarthrosis, then bridged the defect on the medial and lateral aspects by heavy homogenous grafts, transfixing the tibial fragments and grafts by Vitallium screws, of which two were placed proximally and two distally. The interval between the grafts was filled with chips.

Barney Brooks reported in 1920 the results of a series of experiments on dogs in which a bone graft was partially prepared, the wound was closed, and the graft was removed ten days later. Alizarin red was injected in order to stain the new bone which was formed. A total of seventeen experiments led Brooks to conclude that the os novum type of graft was more osteogenetic than the direct transplant, particularly in growing bone. Experimental work reported in earlier publications, substantiated his conclusions.

In spite of the great advances made in bone-graft surgery since 1900, the results in congenital pseudarthrosis have been extremely discouraging. Mercer stated that Putti, in thirteen cases, had two recoveries. Nové-Josserand reported seven cases with three recoveries. Froelich had four cases with two failures. Campbell, in 1939, saw three cases, of which two were failures. Boyd, in 1941, reported six cases, with two failures.

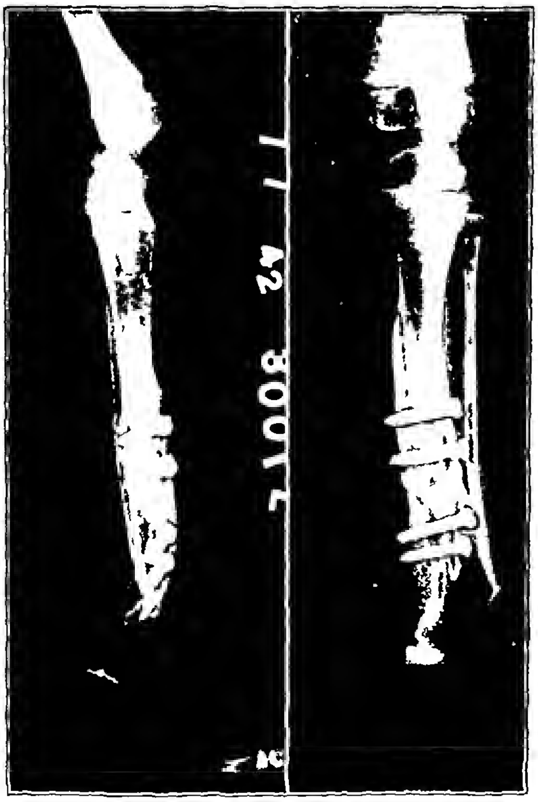

FIG. 2-A

Fig. 2-A: A. E. Lateral and anteroposterior roentgenograms of the tibia and fibula show congenital pseudarthrosis. Note refracture through dual onlay graft. Three delayed graft procedures were necessary because of two spontaneous fractures. Fig. 2-B shows present status.

FIG. 2-B

Fig. 2-B: Anteroposterior and lateral roentgenograms show tibia and fibula one year after delayed graft. Note restoration of continuity of tibia and fibula, and of medullary cavity.

CLASSIFICATION OF PSEUDARTHROSIS

The outlook for the successful treatment of congenital pseudarthrosis would be extremely grave, were it not for the fact that bone continuity can be successfully restored through bone-grafting Bone-grafting has for its primary purpose the stimulation of osteogenesis It is obvious from the foregoing historical review that osteogenesis has been restored in many instances, with restoration of the skeletal defect and return of function One might theorize that the end product of osteogenesis (laminated bone) in the pseudarthrosis area is defective in quality, in that it is not only incapable of withstanding the physiological stresses, but is equally incapable of repair This is the author's working hypothesis, and is the basis for his classification of congenital pseudarthrosis into two principal types

1 *Pre-pseudarthrosis* In this stage the long bone is bowed or bowing, the apex of the bow is narrow, the medullary cavity becomes obliterated, and spontaneous or induced fracture (often surgical) occurs, followed by pseudarthrosis

2 *Pseudarthrosis* Various degrees may occur, from simple fibrous to frank nearthrosis, including sclerosis of the bone ends, cartilage, and joint cavity

It is with this hypothesis in mind that the delayed autogenous bone graft is presented, it is an excellent means of producing osteogenesis

THE DELAYED AUTOGENOUS BONE GRAFT

Preparation of the Graft

The delayed autogenous bone graft is a graft that is elevated from the tibia, fibula, or ilium, completely freed of all attachments, replaced in its natural bed, and, after routine closure, by layers, of the periosteum, subcutaneous tissue, and skin, is allowed to remain so imbedded for an average period of eighteen to twenty-one days It is next removed subperiosteally, care being taken to preserve the new-bone attachment to its various surfaces It is then implanted in the fragments comprising the pseudarthrosis

Preparation of the Pseudarthrosis Site

Infection, if present, must be eliminated six months before grafting Skin scars, adherent or wide, must be excised and healed one or two months before grafting

The deep approach to the tibia or to the tibia and fibula should be made through the anterior compartment of the leg The pseudarthrosis should be excised completely, including all fibrous tissue and the sclerosed bone ends The tibial and fibular fragments should be aligned perfectly and then held in position, each is transfixed by two heavy Kirschner wires All of the wires should be in the same plane, approximately one inch apart, and placed well away from the exposed ends of the tibial fragments Care should be taken to avoid the epiphyseal lines The author usually employs the Abbott bone-lengthening apparatus for directing the pins and holding the fragments while the graft is being inserted One of the two lower pins occasionally has to be inserted into the calcaneus The fibular fragments are fixed by an intramedullary Kirschner wire

Implantation of Grafts

The tibial fragments are split as far as the nearest transfixion wire The tibial graft is wedged at the ends and forced between the split surfaces of the proximal and distal tibial fragments A smaller fibular graft is prepared, similar to the tibial graft, it is laid against the fibular fragments and fixed, if necessary, with a fine wire suture above and below As previously stated, both the tibia and fibula are approached through the anterior muscle compartment This necessitates retracting the muscles, vessels, and nerves away from each bone, in order to gain proper exposure A single skin incision suffices for the exposure of both bones

FIG 3-A

Fig 3-A. P. B. Anteroposterior and lateral roentgenograms, taken July 7, 1943, show congenital pseudarthrosis of the lower third of tibia and fibula. Note fracture through dual onlay graft.

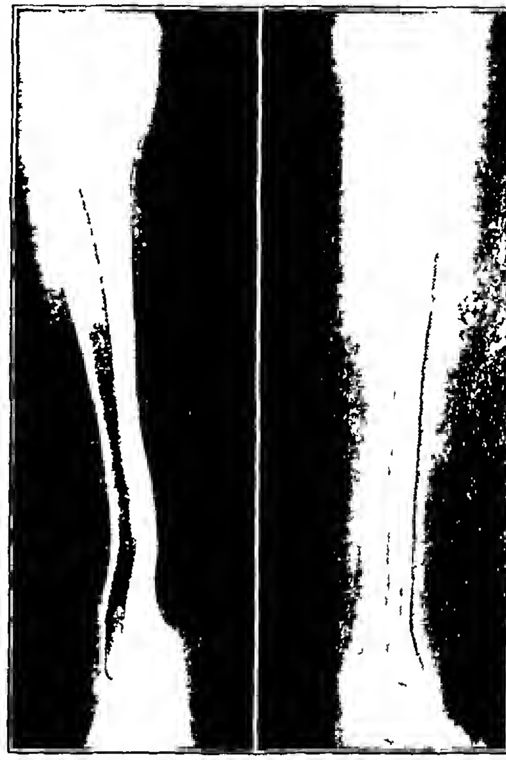

FIG 3-B

Fig 3-B. Anteroposterior and lateral roentgenograms of tibia and fibula show restoration of continuity of both tibia and fibula, one year after delayed graft. Note bowing. This must be watched carefully, and new bone must be added if evidence of weakening appears.

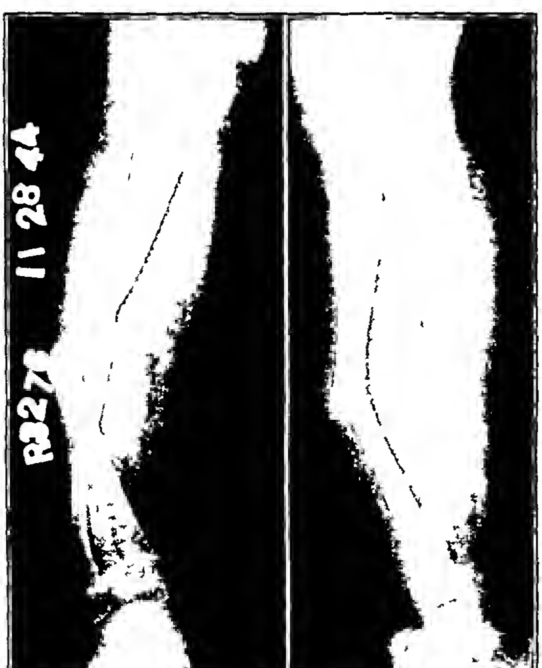

FIG 4-A

Fig 4-A. L. C. Anteroposterior and lateral views of the right tibia show congenital pseudarthrosis.

Fig 4-B. Anteroposterior and lateral views of the right tibia, twenty-two months after delayed bone graft.

FIG 4-B

The wound is closed in layers, including the two incisions in the compartment employed for the tibia and fibula, the incision in the anterior wall of the compartment, and

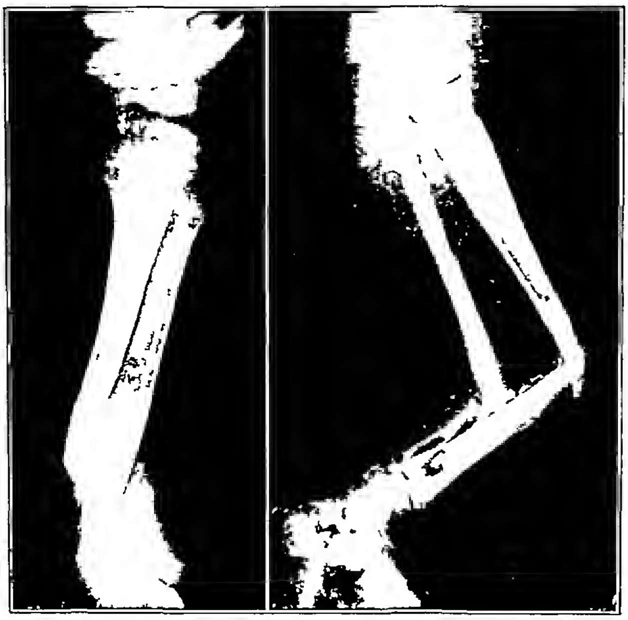

Fig 5-A

Fig 5-A G J Anteroposterior and lateral roentgenograms of lower third of the left tibia, April 18, 1946

Fig 5-B Anteroposterior and lateral views, October 16, 1947, eighteen months after delayed graft Note restoration of continuity of both tibia and fibula, medullary cavity has been restored Slight anterior and medial bowing persists and, if progressive, grafting will be necessary (subperiosteal grafts)

Fig 5-B

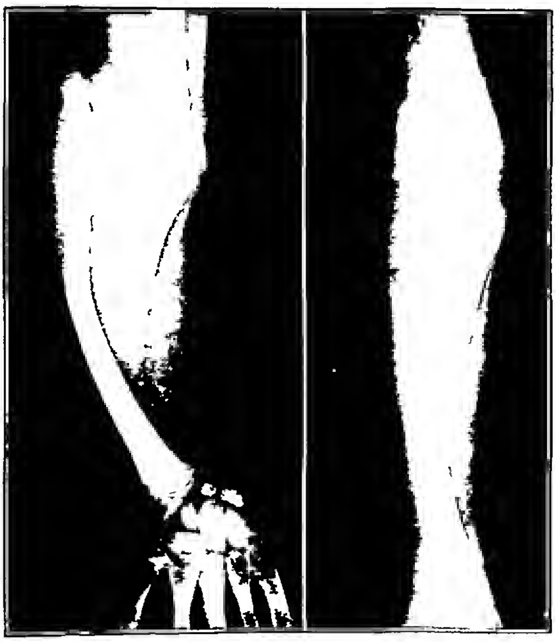

Fig 6-A

Fig 6-B

Fig 6-A F M Anteroposterior and lateral roentgenograms, taken April 8, 1947, show congenital pseudarthrosis of left ulna

Fig 6-B Anteroposterior and lateral roentgenograms, eight months after delayed bone graft Note restoration of continuity of medullary cavity Ulna not growing as rapidly as radius Radial bowing was corrected, prior to delayed graft, by delayed osteotomy Radial growth arrest is indicated Pin in lower portion of ulna represents method of fixation employed to attach delayed graft to distal ulnar epiphysis

finally, the subcutaneous tissue and skin Immediately before closure, the tourniquet is removed and complete hemostasis is obtained Routine light dressings are followed by a plaster cylinder, including pins, which extends from toes to groin

Fig 6-C

Photomicrograph (× approximately 125) of bone graft, initial stage This section shows adult laminated bone with viable lacunae cells

Fig 6-D

Photomicrograph (× approximately 125) of bone graft, second or delayed stage In one portion of the section there is a piece of adult bone which is now dead Note the empty lacunae arising from this new-bone formation with osteoblastic activity and primitive bone spicules

If leg-lengthening is to be performed, the pseudarthrosis is excised and the apparatus for lengthening is applied The lengthening should be done very slowly,—one-sixteenth of

Fig 7-A

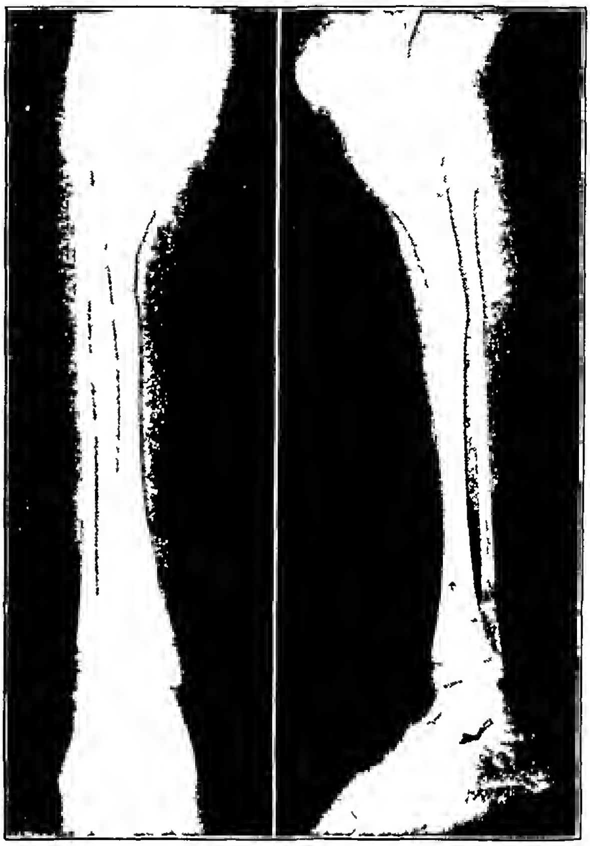

Fig 7-B

Fig 7-A J S Roentgenograms, taken October 24, 1946, following congenital pseudarthrosis in the upper third of the right tibia

Fig 7-B Anteroposterior and lateral views of the right tibia, nine months after delayed graft Note continuity, restoration of the medullary cavity nearly complete Mild posterior bowing must be carefully watched and regrafting must be done, if necessary (subperiosteal graft on the concave side of the bow)

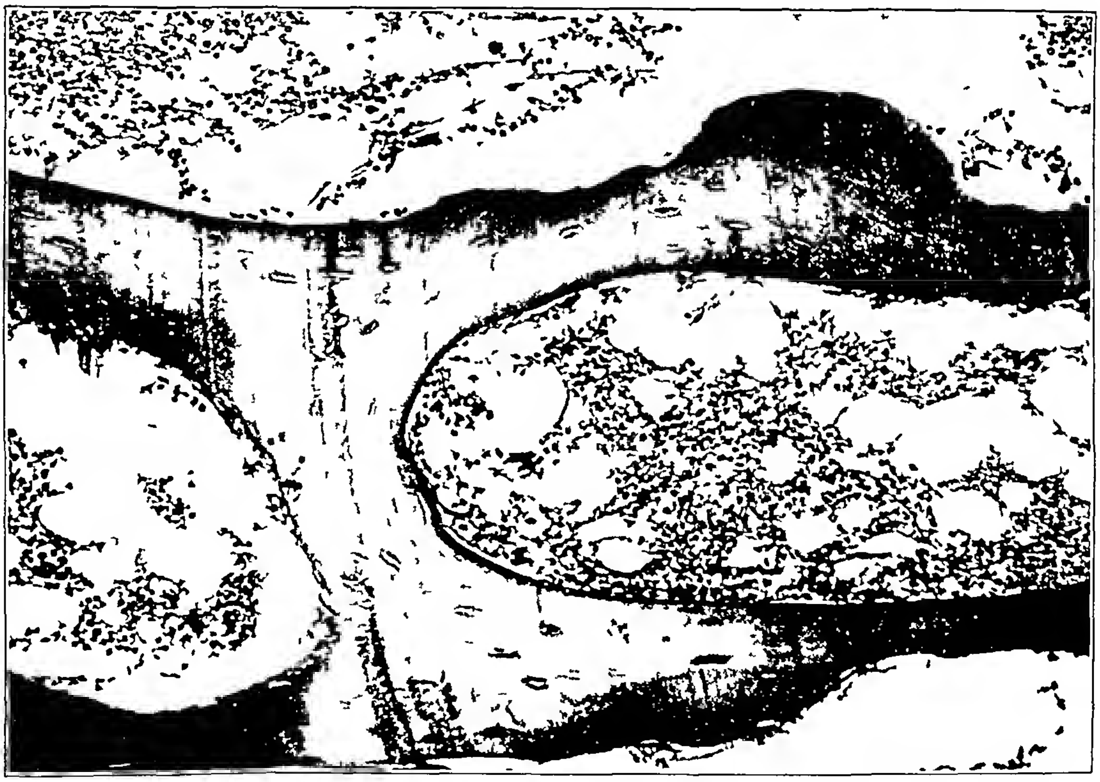

Fig 8-A

C K Photomicrograph (X approximately 125) of bone graft, initial stage Section shows normal adult bone, the viability of which is demonstrated by the presence of osteoblasts and lacunae

an inch daily, beginning on the seventh day. The maximum length obtained in the present series was three and one-half inches. *The delayed graft must not be started until lengthening is complete and the operative wound has healed.* The first and second stages of the delayed graft, and the lengthening apparatus and plaster used in primary fixation, are shown in Figure 1. For pseudarthrosis of the ulna, femur, or clavicle, delayed onlay grafts are used, and fixation is obtained by an intramedullary Steinmann pin or a Kirschner wire and Vitallium screws.

After-Treatment

The pins and plaster are maintained until the medullary cavity appears in the graft, which requires an average period of four to six months. A double-bar caliper brace, extending from ankle to groin, is then applied. This brace has a pelvic band and a full-length tibial leather cuff; a removable celluloid tibial cylinder is employed inside the cuff, but not attached to it. The brace is worn for two years.

Pertinent Points in the Technique

1. The bone grafts must overlap the fragments for two inches or more.
2. Fixation with four pins is essential.
3. The graft is held in position until a well-defined medullary cavity has appeared.
4. The application of the graft should not be delayed more than eighteen days in small children, or the graft will lose its identity.

CLINICAL AND LABORATORY DATA

Eight patients with congenital pseudarthrosis are presented; five are females and three are males. At the time of the delayed graft, two of the patients were four years of age, one

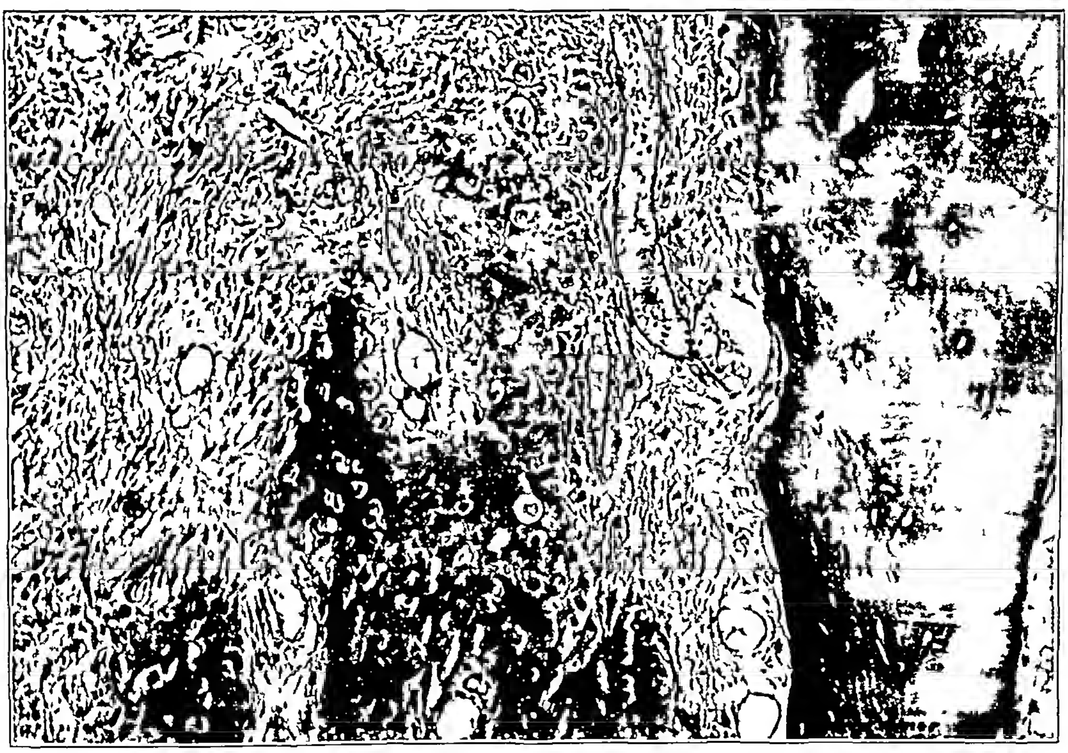

FIG. 8-B

Photomicrograph (× approximately 125) of bone graft, second stage or delayed graft. In one corner there is a piece of adult bone which is dead. Arising from this is new-bone formation in callus. Note the osteoblastic activity.

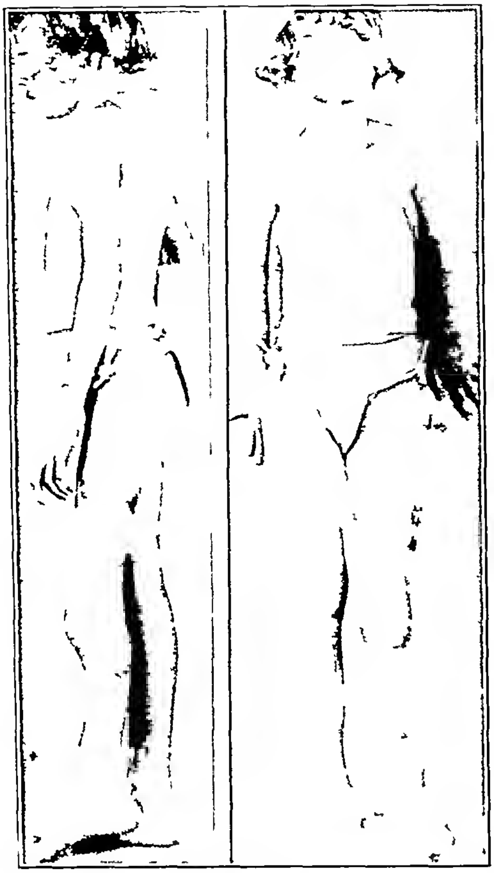

Fig 12-A

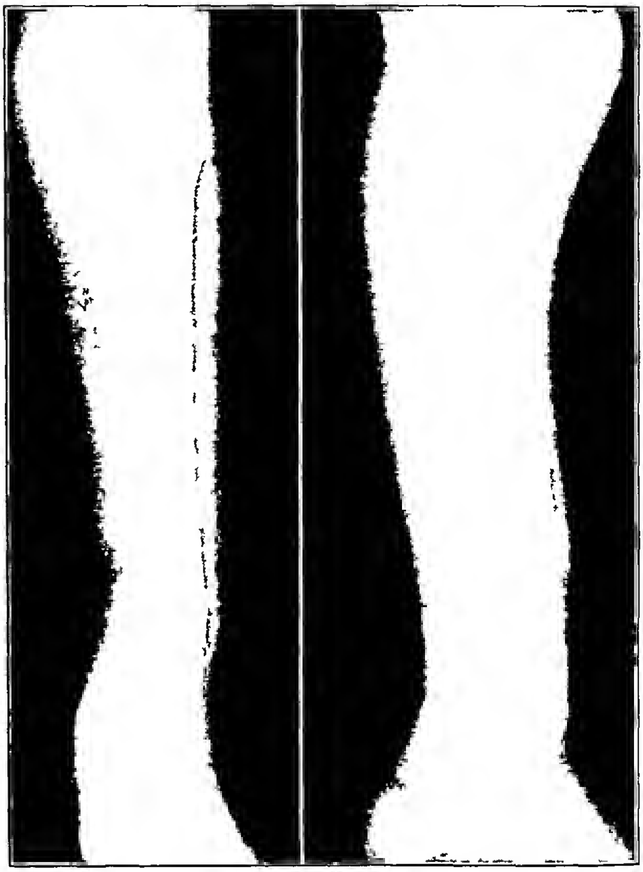

Fig 12-B

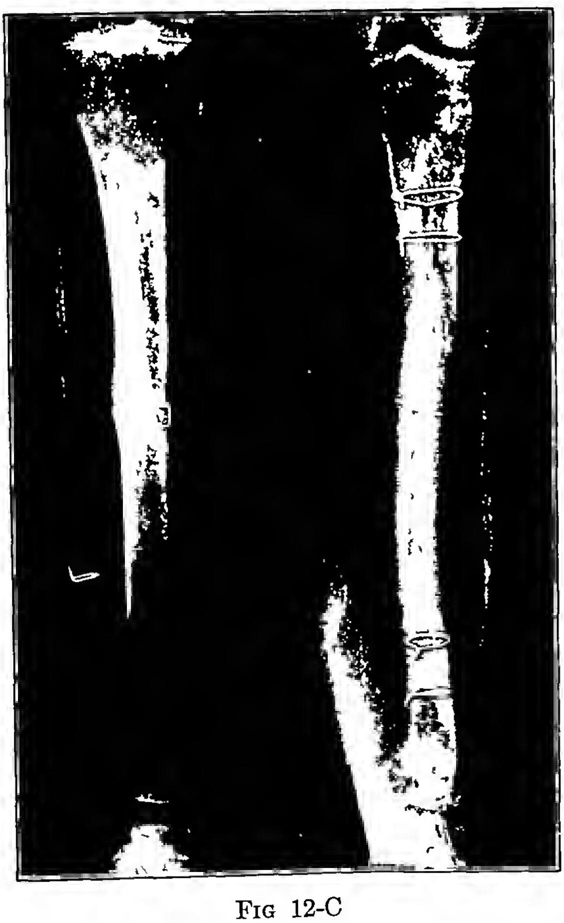

Fig 12-C

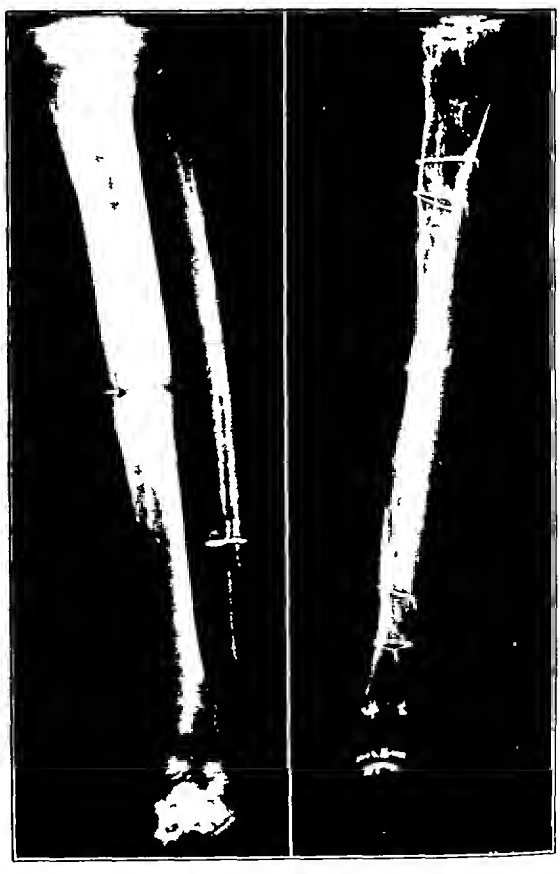

Fig 12-D

Fig 12-A R G Anteroposterior and lateral photographs, taken January 26, 1942, show typical congenital pseudarthrosis Note café-au-lait spots, scarring from previous operations, and shortening

Fig. 12-B. Anteroposterior and lateral roentgenograms show typical congenital pseudarthrosis of lower third of the tibia and fibula on the left.

Figs. 12-C and 12-D. Anteroposterior and lateral roentgenograms of the tibiae and fibulae of both right and left legs. Left tibia shows restoration and continuity of medullary cavity, six years after delayed graft. Lower end of tibia shows a sclerosis, representing the site of correction of the anterior bowing. Correction obtained by delayed osteotomy. The opposite tibia shows the leg-shortening procedure, after nine months.

was six, one seven, two eight, and two twelve. Patients A. E. and P. B. had three applications of the delayed graft, due to spontaneous fractures (Figs. 2-A, 2-B, 3-A, and 3-B). L. C. had additional small shaving grafts, in order to increase the diameter of the graft of the tibia (Figs. 4-A and 4-B).

The average period required before formation of the medullary cavity was six months. Café-au-lait spots were present in seven of the eight cases. Neurofibromata were present in two, G. J. (Figs. 5-A and 5-B) and E. M. In six cases the tibia and fibula were involved; in one case, the femur; and in one case, the ulna. F. M., the patient with pseudarthrosis of the ulna, had a deformed elbow at birth (Figs. 6-A and 6-B). D. M., the patient with involvement of the femur, presented a short lower extremity with thickening of the proximal portion of the thigh. In all cases of tibial and fibular pseudarthrosis, bowings were present at birth and fractures occurred during the first year. Heredity played no noticeable part. J. S. (Figs. 7-A and 7-B) had a brother with pre-pseudarthrosis.

Microscopic studies of material taken from the pseudarthrosis areas revealed mainly hyperplasia of fibrous tissue. A pathologist's report stated: "There is a mass of adult fibrous tissue in which there is collagen production. The interspersed fibrocytes are for the most part adult in type. There is no frank neoplastic proliferation here." *

TABLE I

ALKALINE-PHOSPHATASE DETERMINATIONS

Patient	First-Stage Graft (*Bodansky Units*)	Second-Stage Graft (*Bodansky Units*)	Increase or Decrease (*Bodansky Units*)
J. S.	88	178	+ 90
G. J.	75	180	+105
P. B.	520	662	+142
D. M.	540	320	−220
F. M.	Tests unsuccessful		

In J. S. and G. J., neurofibromata were found in microscopic sections of subcutaneous tumors. The blood calcium, phosphorus, and phosphatase were normal. Other laboratory studies, including Wassermann reactions, were negative. Microscopic sections of the first-stage bone graft showed normal bone. Microscopic sections of the bone graft at the second stage (after eighteen to twenty-one days) revealed the following: "The sections of the delayed bone graft show dead bone of the adult type, from the surface of which there is callus growth with provisional bone formation. Diagnosis: Delayed bone graft with new-bone formation." *

Alkaline-phosphatase determinations were performed on the grafts at the first and second stages in five of the cases (Table I).

Figures 6-C, 6-D, 8-A, and 8-B illustrate the microscopic sections of the delayed grafts; Figures 9 and 10, of the usual soft pseudarthrosis tissue.

Figures 11-A, 11-B, and 11-C show the tibia of M. J. J., before and after application of the delayed bone graft. This nine-year-old patient did not have congenital pseudarthrosis, but a pseudarthrosis due to osteomyelitis. Three and one-half inches of lengthening was obtained. This was the first case of pseudarthrosis in which the delayed autogenous

* Reported by E. E. Aegerter, M.D., Professor of Pathology, Temple University Medical School.

FIG. 13-A

M. M. Anteroposterior roentgenogram, taken January 11, 1947, shows congenital pseudarthrosis of the upper third of the right femur.

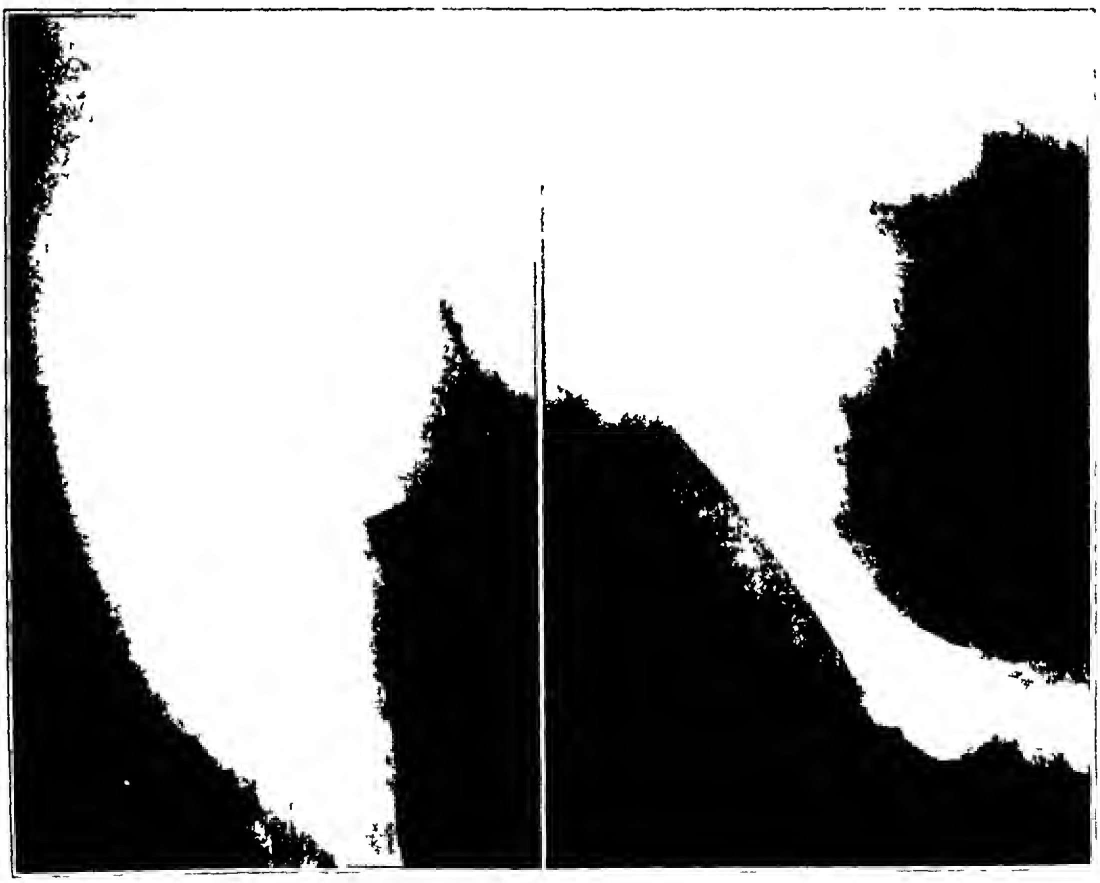

FIG. 13-B

Anteroposterior and lateral roentgenograms, taken September 3, 1947, show restoration of medullary cavity and continuity, eight months following delayed graft. Considerable bowing is present. The condition must be watched and, if progressive, regrafting should be done (subperiosteal graft).

graft was employed. Furthermore, the delayed graft bridged a six-inch defect, three and one-half inches of which had been produced by the leg-lengthening. Success in this case led to the use of the delayed graft in eight cases of congenital pseudarthrosis, as illustrated in Figures 2-A to 7-B and 11-A to 13-B, inclusive.

RESULTS

Successful osteosynthesis has been accomplished in eight cases of congenital pseudarthrosis. In six of these cases the deformity was in the leg, once it was in the ulna, and once in the femur. In five cases the period of follow-up ranged from eight months to a year; in the other three cases it was eighteen months, twenty-two months, and four years, respectively. In two cases three delayed grafts were required, and in one case an additional bone was required for thickening, to prevent possible breaking. In one case a delayed osteotomy was performed through the healed pseudarthrosis area, to correct severe anterior bowing. In the pseudarthrosis of the tibia with a six-inch bone defect, restoration of the defect was accomplished by the delayed autogenous graft. In two cases spontaneous fracture occurred, and traumatic fracture occurred once in each of these cases, necessitating the extra grafting mentioned previously. Anterior bowing occurred in each of the cases of spontaneous fracture, and simulated the bowing seen in pre-pseudarthrosis. Grafting the fibula, better bracing, and improved after-care might have solved this problem.

CONCLUSIONS

The delayed autogenous bone graft is capable of stimulating osteogenesis. The extra supply of alkaline phosphatase and the attached newly formed bone may contribute to osteogenesis. Bony union occurred in each instance. The principal problem is one of meticulously nurturing the young bone until it can withstand the physiological forces and, later, the functional demand. Reinforcement of the newly formed tibia at its weak point, as evidenced by narrowing or incipient bowing, is imperative. Osteosynthesis of the fibula is believed to be of great value, not only in offering additional strength to the young tibia, but also in maintaining axial alignment. The importance of the continuation of primary immobilization until the medullary cavity has been formed, cannot be overemphasized. It offers the only criterion for the discontinuation of primary immobilization, by means of four pins and plaster fixation. A bimonthly roentgenographic check-up is essential during the first two years.

The follow-up period in all of the cases is probably too short to justify final conclusions. The fact that union occurred in every case in which the delayed graft was used, including those cases in which re-operation was done, is distinctly encouraging, and points to the effectiveness of this type of graft. In L. C., bending started at a narrowed point in the tibial graft, but prompt reinforcement with cortical grafts (not delayed grafts), at the site of the apparent weakness, prevented spontaneous fracture and brought about proper restoration. In the two cases in which spontaneous fracture occurred, it could probably have been avoided, had early bending been detected and the area been reinforced. In addition, if the policy of reinforcement were employed early—that is, when the graft became narrowed or at the time of the incipient bending—the danger of spontaneous fracture would be reduced.

The treatment of congenital pseudarthrosis will probably never be entirely effective until the etiology has been determined. Osteosynthesis by bone-grafting still offers the principal means of attacking the problem. It is the author's belief that improvements in surgery, in bone-grafting, in bone-graft material, and in fixation, protection during the follow-up period, and early reinforcement of weak grafts will offer greater hope of successful treatment and will reduce the number of failures and amputations.

NOTE: Translations of French and Italian articles were made by Miss Mary Vanderhoof, through the courtesy of George E. Bennett, M.D.

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DISCUSSION

Dr. William T. Green, Boston, Massachusetts: Dr. Moore's contribution is one of major importance. Congenital pseudarthrosis of the tibia and fibula is one of the most difficult conditions in which to

obtain osseous union, at least in early childhood The results that he has shown, which I assume represent consecutive cases, are far better than have been obtained in any other series of which I am aware

Some of the factors that may enter into the results which he has obtained are

1 The technique of delayed bone-grafting
2 The use of the lengthening apparatus to immobilize, and to obtain length where necessary
3 The thorough excision of interposed soft tissue and of the abnormal bone at the site of the defect
4 The use of a graft long enough to extend well across the site of non-union into good bone
5 The use of a graft for the fibula as well as for the tibia
6 The strengthening of the area by additional grafts, when necessary, before fracture occurs

Of these technical points, the one which we have not used and the one which I believe is of great importance is that of the delayed bone graft That represents an evolutionary step from the work of Orell, who implanted beef bone, especially prepared so as to remove the organic material, into the front of the tibia This beef bone, which he called "os purum", stimulated the formation of new bone, which he appropriately called "os novum" He then transplanted this os novum, either with or without the os purum Dr Moore has produced his os novum in another way, with the additional advantage that the rest of the graft is not beef bone, but autogenous bone of a mass which gives stability

In the transplantation of bone, only those cells immediately in relation with tissue fluids survive In Dr Moore's technique, the graft is left *in situ* long enough for the proliferation of new bone which, when transferred, should preserve its viability Whether or not it does, could and should be substantiated experimentally

Dr Moore has given his technique a rigorous test in the problem of pseudarthrosis, and the results have been excellent The question arises immediately as to whether the technique should not be used widely in other conditions The objection which might be raised is that its use requires an additional operation and a period of disability, preliminary to the transplantation of the bone However, the incidence of non-union after bone-grafting is frequent enough, particularly in certain conditions, so that I feel the value of the method must be explored in a wider range of uses The short additional time necessary at the start in this technique is certainly worth while if it diminishes the percentage of non-union and shortens the period of disability after the transplantation

It does not seem appropriate to discuss the relation of neurofibromatosis to pseudarthrosis, since this will only detract from the emphasis I would like to place upon the technique which has been described This was an excellent paper, time will determine its full significance

Granting that Brooks described a similar delayed graft some years ago, it has not lived as a working procedure

Dr Dallas B Phemister, Chicago, Illinois The successful healing obtained in such a high percentage of cases is evidence of the merit of the procedure employed by Dr Moore It is necessary to evaluate both the mechanical and the biological principles involved in order to decide their relative roles in the success of the operation

The mechanical principles all seem to be sound and, since they were well applied, were undoubtedly of great importance

From the biological standpoint, the fracture occurs through a segment of the tibia, and perhaps also of the fibula, which is the seat of congenital local imperfect osteogenesis Removal of the defective and often extensively absorbed segment, by excision of the fragment ends and replacement by an autogenous graft from healthy bone, has points in its favor, although addition of the onlay graft, with as much as possible of the fragment ends preserved, helps to maintain a larger volume of bone and has long been used with success Sometimes the fragments are fairly well preserved at the fracture level, in which case the question arises of whether an ample onlay graft may not work as well as complete substitution When the delayed graft is used, callus forms along its periosteal and endosteal surfaces from surviving unossified osteogenic cells, during the three-week period between the cutting and the transference, this is partly fibrous and partly spongy bone This callus participates in the establishment of union, and the subsequent creeping replacement of the necrotic cortex of the graft by new bone After transplantation, more unossified osteogenic cells may survive in this callus than in the periosteum and endosteum of a fresh transplant The procedure looks promising, but perhaps more control operations should be performed, the same mechanical procedure being used, but with freshly cut grafts

Dr Charles W Peabody, Detroit, Michigan The Spanish surgeon, Dr Trueta, who since 1939 has been an active surgeon on the staff of the Wingfield Morris Hospital at Oxford, England, is now traveling in this country, and I was recently favored by a visit from him He mentioned some recent experiences with the problem of pseudarthrosis, and Dr Moore's illustration of prolonged skeletal fixation may make pertinent the mention of Dr Trueta's conclusion

Dr Trueta reported that his last four cases had been cured by the use of the Kuntscher intramedullary

(*Continued on page 66*)

APPROACH TO AND EXPOSURE OF THE HIP JOINT FOR MOLD ARTHROPLASTY

BY M. N. SMITH-PETERSEN, M.D., BOSTON, MASSACHUSETTS

A joint has two surfaces which must be so shaped as to be able to function without interference or impingement through the greatest possible arc. Consequently, in the case of the hip joint, it is necessary to expose the acetabulum and its adjacent structures as well as the femoral head and neck. In the past the various approaches to the hip joint have failed to properly expose the acetabulum and the surgeon's efforts have been directed mainly at partial reconstruction of the femoral head. Reconstruction of the acetabulum demands intrapelvic exposure of this side of the joint. The approach to such an exposure necessitates extensive dissection, since this can be carried out along structural planes, it is not destructive (Figs. 1 and 2).

The skin incision extends from the junction of the middle and anterior thirds of the iliac crest to the anterior superior spine, deviating slightly laterally along the medial border of the tensor fasciae latae (Fig. 3).

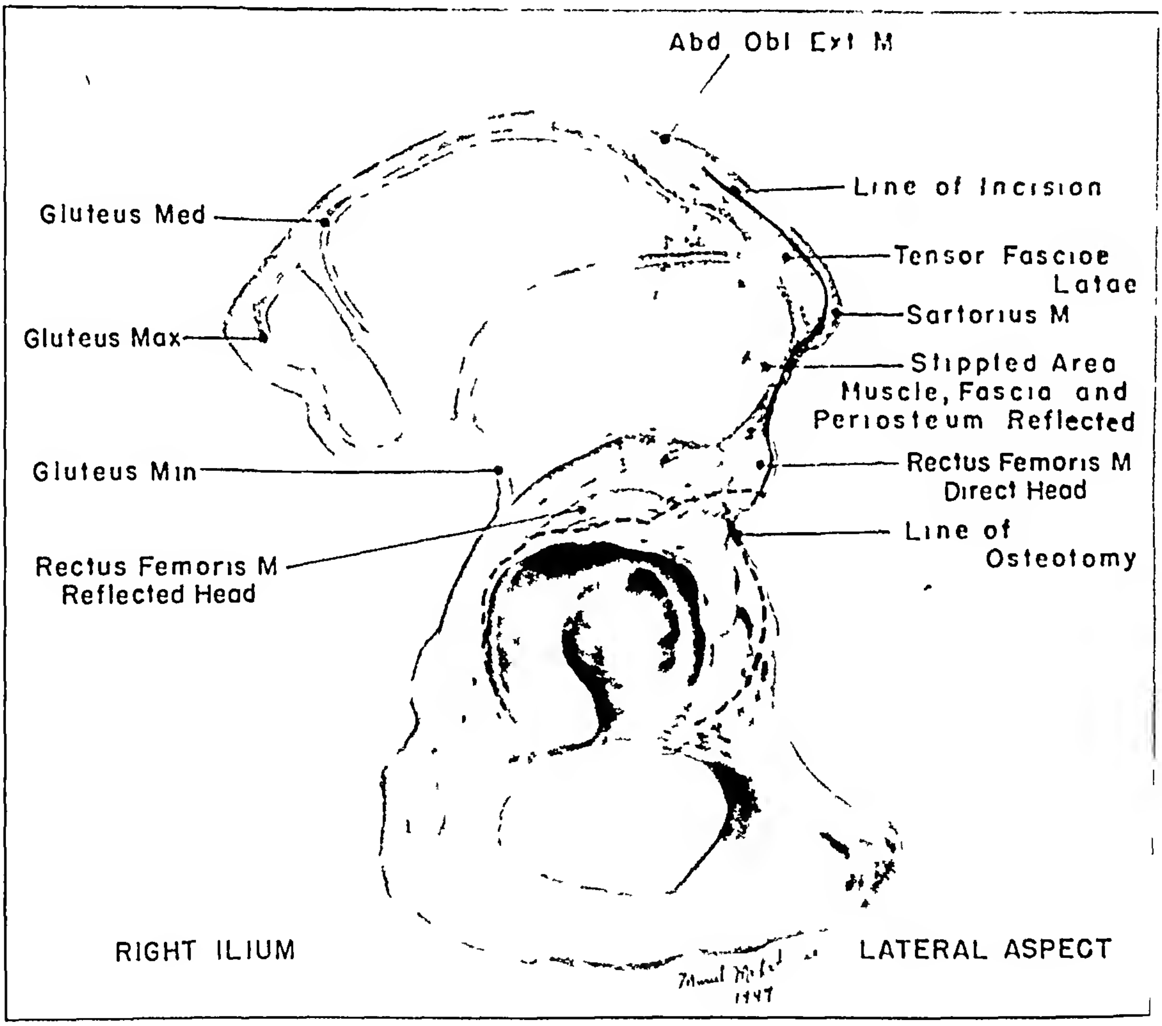


FIG. 1

Lateral aspect of ilium.

The purpose of this diagram is to demonstrate the extent of the osteotomy and reconstruction of the acetabulum necessary for mold arthroplasty.

The dotted line represents the line of osteotomy, the stippled area represents the extent to which the periosteal muscular attachments must be reflected.

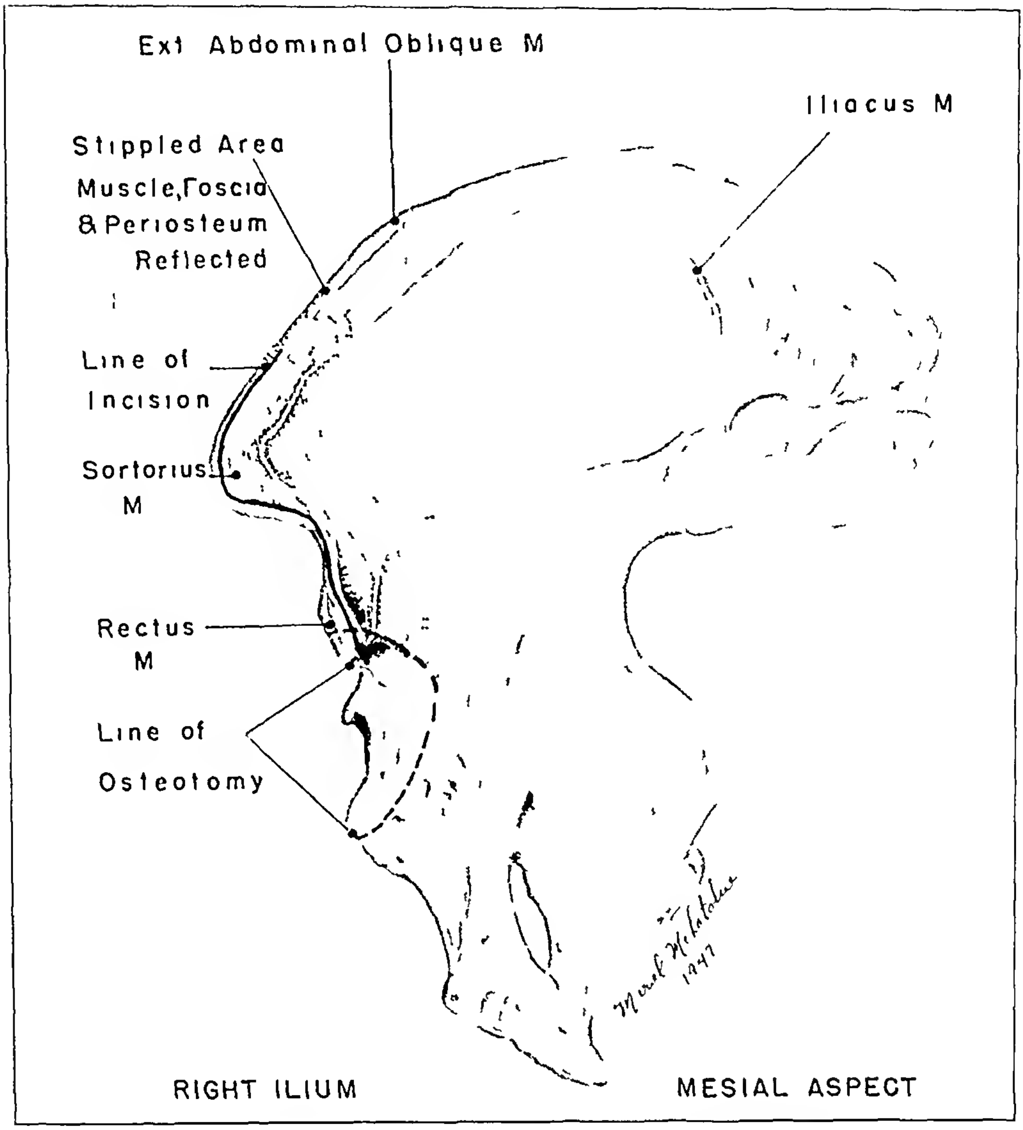


Fig 2

Medial aspect of ilium

The purpose of this diagram is the same as that of the preceding one It also shows the line of incision of the periosteum between the external abdominal oblique and the sartorius medially, and the glutaei and tensor fasciae latae laterally

It should be noted that the osteotomy includes the inferior half of the anterior inferior iliac spine

The superficial fat and fasciae are incised down to the deep fasciae covering the external abdominal oblique and gluteal muscles, superiorly, and the sartorius and tensor fasciae latae, inferiorly Between the sartorius and the tensor fasciae latae is a fat compartment, covering the upper portion of the rectus femoris By incision of the femoral fascia between the sartorius and the tensor fasciae latae, a plane of cleavage becomes apparent between the posterior surface of the sartorius and the anterior surface of the iliopsoas as it emerges from underneath Poupart's ligament This plane of cleavage is easily developed by blunt dissection (Fig 4)

Attention is now directed towards developing the superior portion of the approach The plane of cleavage between the abdominal and gluteal fasciae is defined and an incision is made through the periosteum, down to bone By periosteal reflection of the attachments of the abdominal muscles, sartorius, and Poupart's ligament, medially, and of the glutaeus medius, tensor fasciae latae, and glutaeus minimus, laterally, the anterior third of the ilium is exposed (Fig 4)

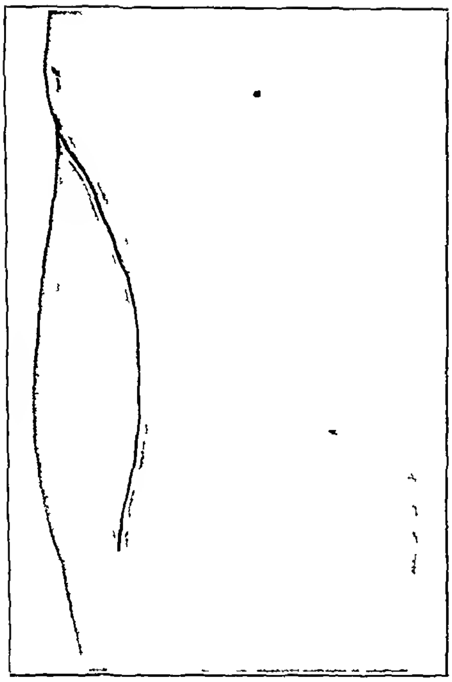


FIG. 3

Skin incision

Depending upon the character of the operation to be performed, the direction of the anterior limb of the incision may be varied. If the greater trochanter is to be transplanted, the incision must be extended laterally across the iliotibial band distal to the insertion of the tensor fasciae latae.

In order to expose the anterior capsule of the hip joint, the deep iliac fascia is divided between the main origin and the acetabular origin of the iliacus muscle. The motor fibers from the femoral nerve to the rectus femoris must always be exposed; they are surrounded by fat and lie on the anterior surface of the iliacus muscle, directly beneath the iliac fascia as this becomes confluent with the deep femoral fascia (Fig. 5).

The anterior inferior iliac spine has now been exposed. Attached to it we have the direct head of the rectus femoris muscle and the acetabular origin of the iliacus muscle, medially; laterally, the reflected head of the rectus is concealed in the supra-articular fat compartment.

All joints have periarticular fat compartments, the function of which is to facilitate the gliding mechanism close to the joint. In the case of the hip joint, we have such fat compartments medially, inferior to the origin of the iliacus from the iliac fossa, and laterally, between the superior aspect of the capsule and the inferior origin of the glutaeus minimus. Between the inferior capsule and the iliopsoas tendon is a similar fat compartment, containing articular branches from the lateral circumflex femoris artery.

It is important to define these fat compartments in order to expose the capsule with its ligaments. By retraction of the iliopsoas medially, the anterior and inferior portions of the capsule of the hip joint are exposed (Fig. 5). The rectus muscle and the acetabular

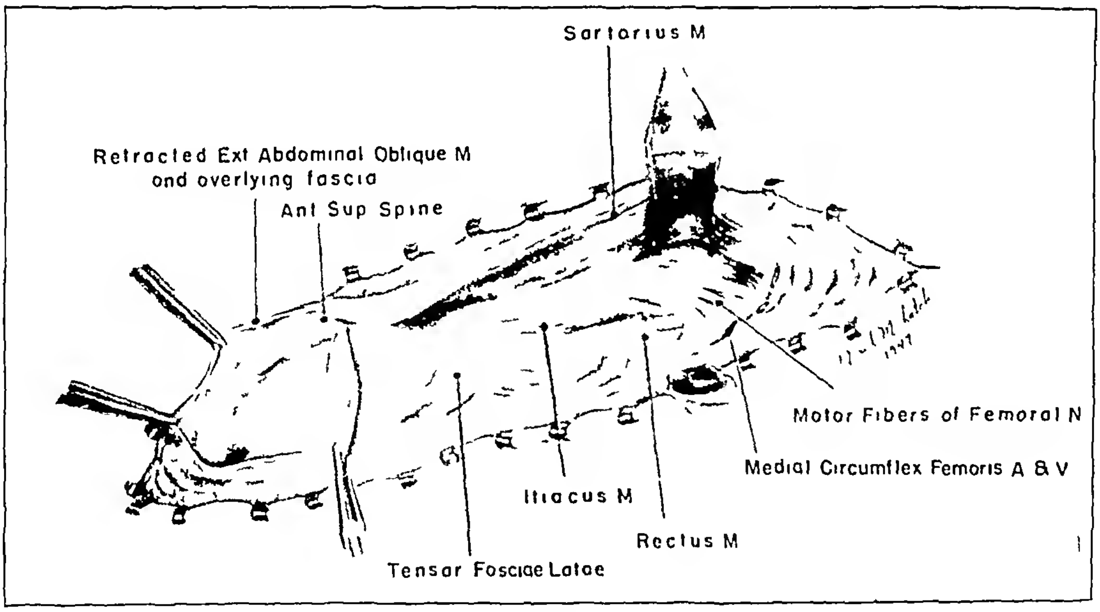


FIG. 4

Structural planes

The anterior limb of the incision has been developed, exposing the iliacus with the overlying motor fibers of the femoral nerve. The tendinous structure of the rectus femoris is not shown, because it is embraced by the acetabular origin of the iliacus. Superiorly, the muscular periosteal attachments have been reflected from the medial and lateral surfaces of the ilium.

The sartorius is muscular at its origin, the tensor fasciae latae is tendinous. There is less tendency to fraying of the sartorius, if the line of division is carried through the tendinous portion of the tensor fasciae latae.

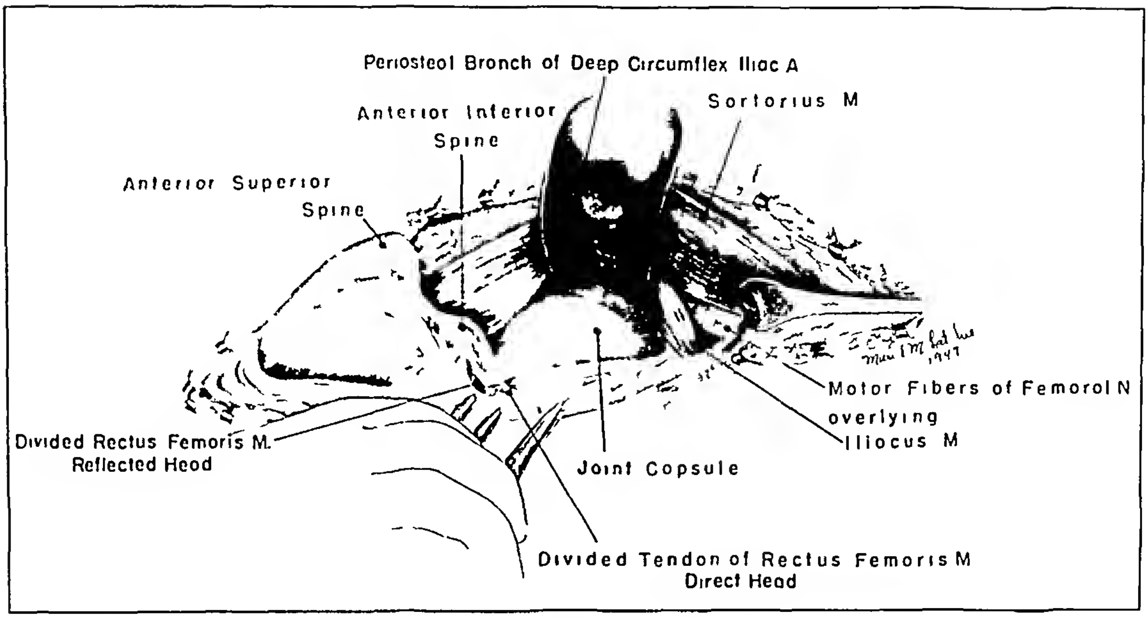


FIG 5

Exposure of joint capsule

Illustrations of surgical procedures are often inaccurate, sometimes actually misleading The text states that the direct head of the rectus is divided and reflected laterally with the Y ligament and fibrous portion of the capsule The diagram shows the rectus divided and retracted, the capsule remaining intact This does occur when the structural planes are intact, but frequently the structures anterior to the joint capsule cannot be identified and then it is wise to include the fibrous capsule and the ligaments in the flap to be retracted laterally In any and all cases, as complete a synovectomy as possible is carried out

The indefinite area above the divided, reflected head of the rectus femoris represents a fat compartment Nutrient arteries enter the ilium at this level, so it is better not to carry reflection of the periosteum below the origin of the glutaeus minimus, it is easier to put a snap on an artery in soft tissues than to plug a nutrient foramen Soft-tissue dissection is carried out between the glutaeus minimus and the reflected head of the rectus, dividing all structures resisting dislocation

The periosteal branch of the deep circumflex iliac artery can as a rule be identified, clamped, and tied Inferior to the capsule and pubofemoral ligament is a fat compartment containing venous and arterial articular branches, these are easily controlled by diathermy It is necessary to develop this compartment in order to be able to divide the capsule and ligaments completely, these structures are often contracted and resist dislocation The iliopsoas tendon forms the floor of this compartment, it is a good guide to the lesser trochanter

origin of the iliacus muscle are divided close to the anterior inferior iliac spine and reflected laterally with the limbs of the Y ligament of Bigelow and the fibrous portion of the joint capsule

An osteotomy of the anterior inferior iliac spine and the anterior acetabular wall is now performed Attached to this bony structure are remnants of the fibrous capsule and the synovial membrane, these are all excised with due respect for the distal attachment of the capsule, since this is the point of entrance of the circulation to the head and neck By this procedure the acetabulum and the anterior aspect of the head and neck are exposed, rendering both sides of the joint available for complete reconstruction

Arthroplasty of any type requires dislocation of the joint In the case of the hip joint this step is often difficult By sacrificing the inferior half of the inferior iliac spine and the anterior acetabular wall, before an attempt is made to dislocate the hip, this manoeuvre is greatly facilitated (Figs 6 and 7) The extent and type of reconstruction of the joint varies according to the condition for which the operation is undertaken

The purpose of the operation is to create a joint with approximately normal mechanics This supplies the clue to the fitting of the mold Normally, joint surfaces glide over one another with a minimum amount of friction, consequently, the mold must be loosely fitted so as to allow the greatest possible range of motion between it and the adjacent, reshaped surfaces of the femoral head and acetabulum (Fig 8)

Before closure of the wound, it is advisable to try out the function of the joint as far as

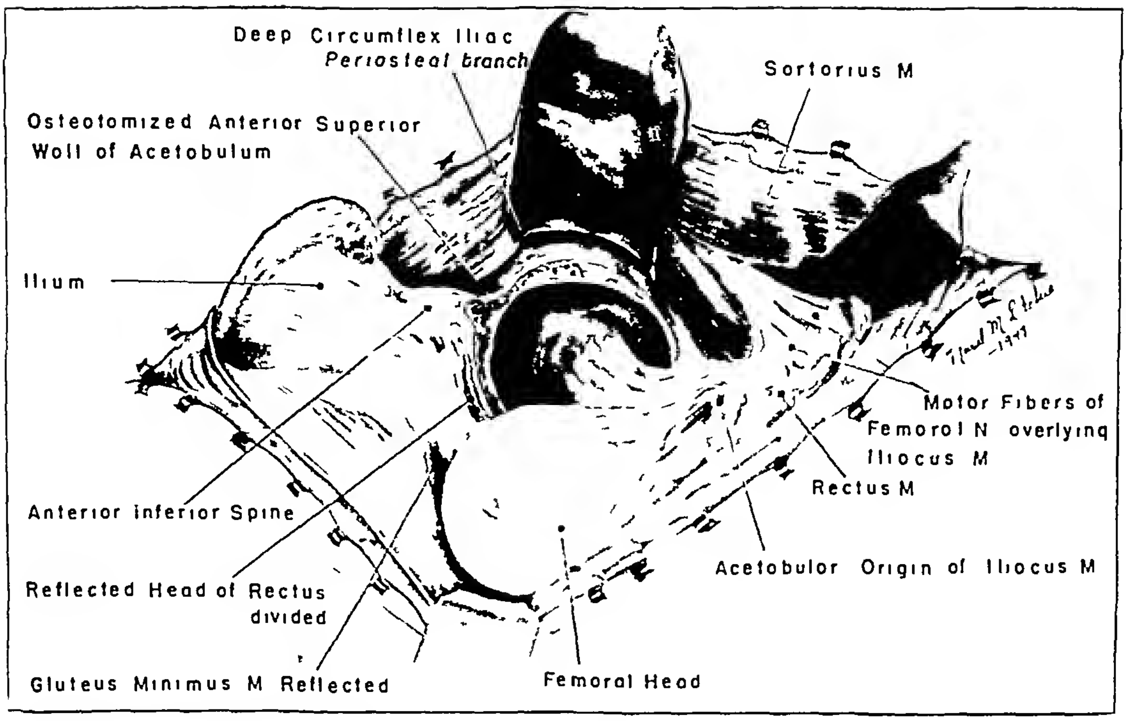


FIG. 6

Dislocation of the hip.

It is unwise to attempt to dislocate the hip without first doing at least a partial osteotomy of the acetabulum and excision of the anterior portion of the capsule. In some cases of malum coxae senilis, with large, deformed femoral heads and osteophytes along the articular margin, it is helpful to begin reshaping the head before dislocating the hip.

It is hardly necessary to point out the need of dividing the superior and inferior capsular structures completely.

This diagram shows an extreme displacement of the femoral head from the acetabulum. It is in the exceptional case only that such an exposure is obtained.

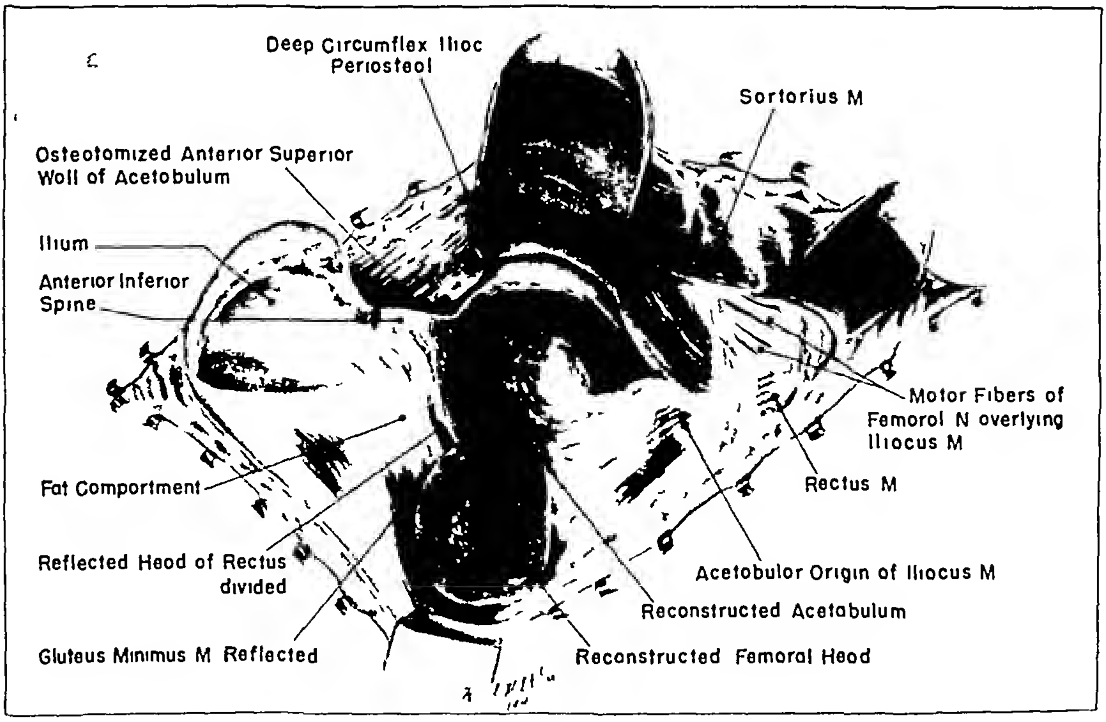


FIG. 7

Plastic procedure completed.

The femoral head and the acetabulum have been reconstructed. Their surfaces are smooth and congruous. "Congruous" is not exactly the right term, since the acetabulum should always be relatively large as compared with the femoral head. It might be better to say that the surfaces of the

Fig 7 (*Continued*)

acetabulum and the femoral head represent segments of spheres of different diameters, one concave, the other convex

The femoral head may be large, as in malum coxae senilis, or it may be small and deformed, and the femoral neck correspondingly short, as in congenital dislocation of the hip In the majority of hip conditions, it is wise to create a joint space by sacrificing bone from the acetabular side and create "an acetabulum relatively large as compared with the femoral head"

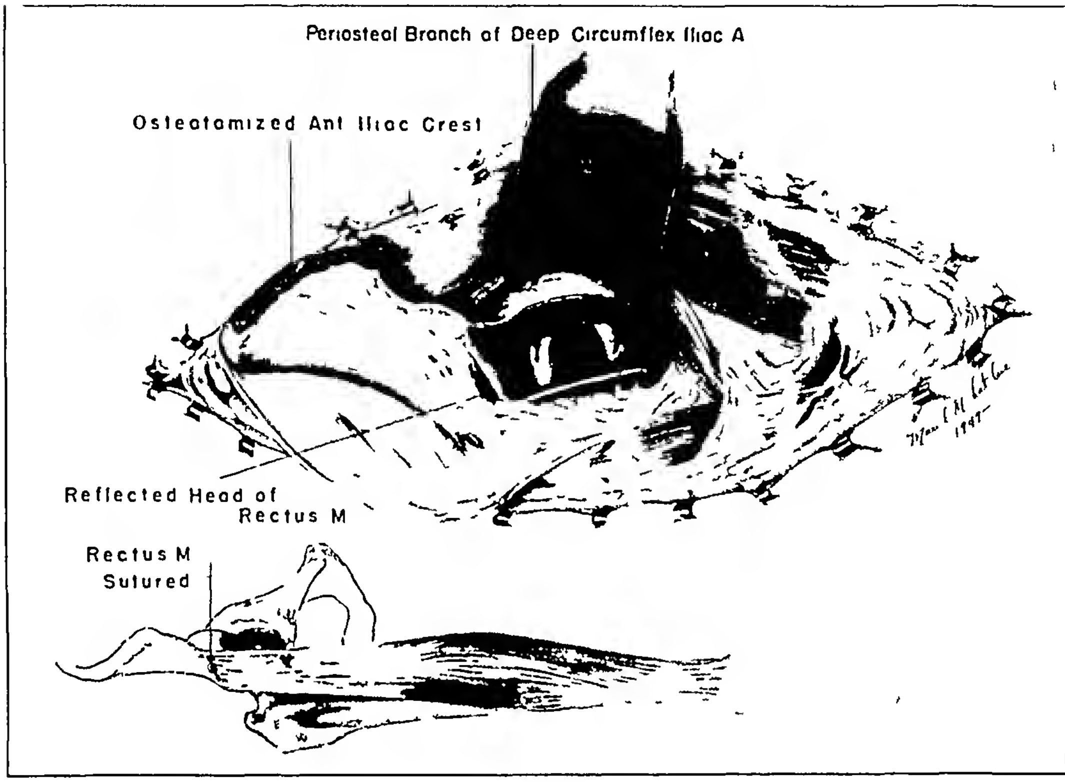


Fig 8

Fitting the mold

Physiological repair demands motion and a minimum amount of friction between the mold and the adjacent reconstructed joint surfaces For this reason the mold should be freely movable in the acetabulum and fit loosely over the femoral head

The mold should be deep enough to allow its edge to extend beyond the margins of the acetabulum If at any point the edge is inside the acetabulum, new-bone formation will grip the edge and prevent freedom of motion of the mold Since the normal hip is a ball-and-socket joint, all motions take place by rotation of one joint surface on the other However, the normal hip is a simple ball-and-socket joint with only two surfaces, whereas the mold-arthroplasty joint is a compound ball-and-socket joint with four surfaces The range of motion in such an artificial joint depends upon freedom of motion between all four joint surfaces If the mobility between the mold and the acetabulum for some reason is restricted, it is important to compensate for it by freedom of motion between the femoral head and the mold In order to obtain freedom of motion in flexion and extension, the femoral head and neck must be so shaped that they will have a tendency to a varus relationship to the mold By this means, flexion and extension will take place by rotation of the femoral head inside the mold and will be independent of mobility of the mold inside the acetabulum In congenital dislocation of the hip, there is invariably a varus relationship of the femoral head and neck to the shaft Patients with this condition, almost without exception, obtain freedom of flexion and extension by arthroplasty

Osteotomy of the anterior iliac crest is done in all cases This allows suturing of abdominal to gluteal structures without tension

range of motion and stability are concerned This gives the surgeon information which enables him to decide upon the optimum postoperative position and to guide postoperative exercises intelligently

The surgical procedure of arthroplasty necessarily creates cancellous bone surfaces Such surfaces have a tendency to proliferate and create spurs or exostoses In our experience, diathermy cauterization diminishes this tendency We, therefore, cauterize the margins or edges of the new acetabulum,—that is, the anterior inferior iliac spine, the anterior

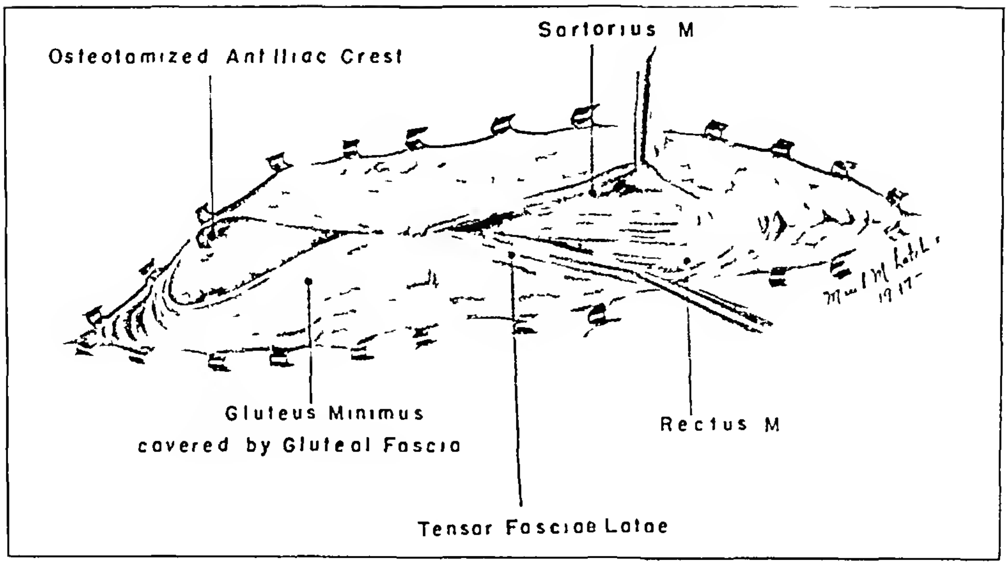


Fig. 9

Closure

The divided tendon of the direct head of the rectus is sutured to the stump of the reflected head of the rectus. If the latter is not intact, the rectus is sutured to the central tendinous origin of the glutaeus minimus.

After osteotomy of the iliac crest, the wound is closed in layers. Since the approach follows structural planes, the closure presents no difficulty.

acetabular edge, the cotyloid notch, and the posterior capsular attachment to the acetabulum.

The closure of the wound is relatively simple, since the approach follows structural planes. The direct head of the rectus muscle is sutured to the reflected head, if this has been preserved; if not, it is sutured to the central tendon of the glutaeus minimus. By excision of the anterior superior iliac spine and crest, the abdominal muscles and fascia are sutured to the gluteal muscles and fascia without tension (Fig. 9). The deep and superficial fasciae are approximated in layers.

Because of uncontrollable oozing from cancellous bone surfaces, there is considerable loss of blood. Transfusions are, therefore, administered from the beginning of the operation in order to prevent serious shock.

AVASCULAR NECROSIS OF LARGE SEGMENTAL FRACTURE FRAGMENTS OF THE LONG BONES *

BY EDWARD L. COMPERE, M.D., CHICAGO, ILLINOIS

From the Department of Bone and Joint Surgery, Northwestern University Medical School, Chicago

Death of the head of the femur has resulted from intracapsular fracture of the femoral neck or from dislocation of the hip [9]. Aseptic necrosis of small bones, such as the tarsal or carpal navicular or lunate bone, and of epiphyses at the distal end of the metatarsals has been described [5]. These are the more commonly recognized locations for aseptic necrosis of bone following trauma. Death of the body of the talus, following fracture or fracture-dislocation, and death of large fragments in segmental fractures of the long bones have been described by Phemister [9, 10], but the clinical significance of traumatic devitalization of portions of the shafts of long bones has not been recognized by many fracture and orthopaedic surgeons.

Greenberg and Mohamed ligated the left femoral artery of rats. Both the right and left fibulae were then fractured. The fracture of the fibula in the leg in which the circulation had not been interfered with healed promptly. There was "a long delay in bone fracture healing" in the fibula of the leg in which the artery had been ligated. The breaking strength in the healing control bone was nearly twice as great at the end of twelve days as was that of the bone in the partially avascular extremity after twenty-four days. This

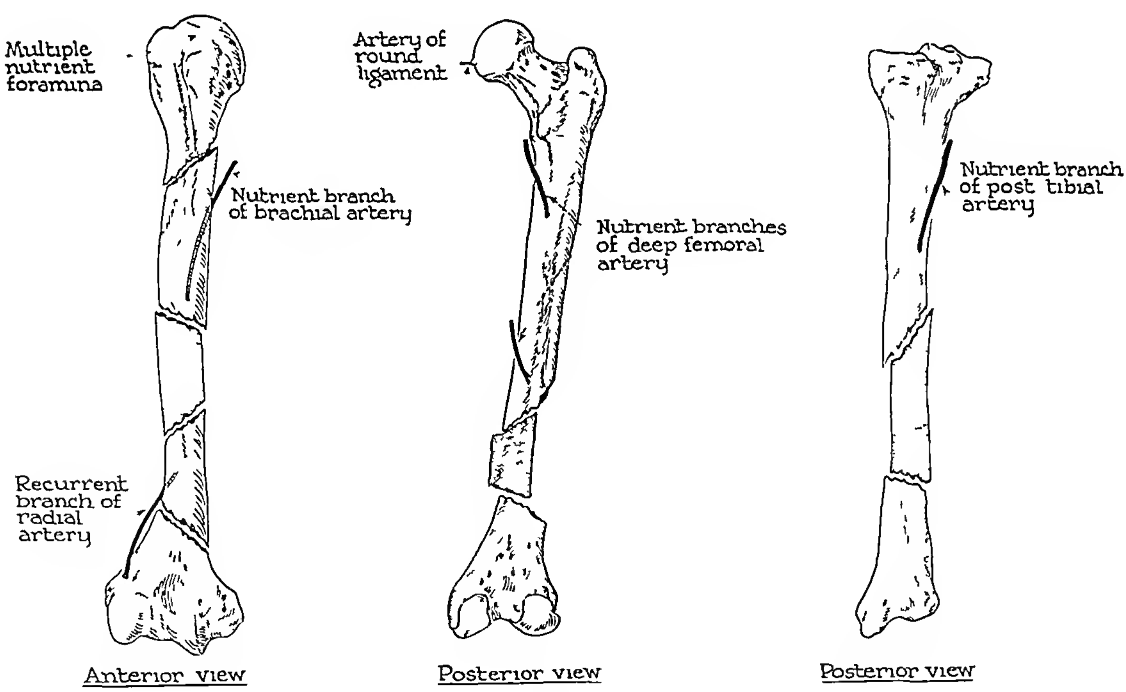


FIG. 1

Diagrammatic illustration of sources of blood supply to the more important long bones. Note that most long bones have only one principal nutrient artery, which is fairly constant with regard to the site of entry. Approximately one-half of the thickness of the outer cortex of the bone is nourished by the very small periosteal communicating vessels. A segment which is completely detached from the end fragments will retain very little blood supply, unless the nutrient artery is intact and supplies this fragment.

* Read at the Joint Meeting of The American Orthopaedic Association, The British Orthopaedic Association, and The Canadian Orthopaedic Association, Quebec, Canada, June 3, 1948.

Fig. 2

Photomicrograph (× 100) of a microscopic section of a full-thickness tibial bone graft, obtained six months after transplantation for fracture of the humerus. The bone cells have disappeared, together with their nuclei, indicating death of the graft.

experiment does show that a marked decrease in blood supply to a bone will delay healing of a fracture.

Brunschwig, while in the Department of Surgery at the University of Chicago, produced aseptic necrosis in the tibiae and femora of young dogs by extensive separation of periosteum from the bone. This deprived the bone of nutrition from nutrient arteries and periosteal vessels. There was no massive sequestration, but the devitalized bone was replaced by creeping substitution. New bone formed from the adjacent living bone and from surviving osteogenetic elements of the separated bone and periosteum.

Johnson has studied the blood supply to the larger long bones. He found that the diaphyses of the bones are nourished by: (1) the nutrient artery, which penetrates the cortex of the shaft and branches to extend toward both ends of the bone; (2) the metaphyseal vessels, a branching network of small arterioles which penetrate the cancellous bone near the ends of the shaft and extend into the medullary tissue; and (3) the periosteal blood supply, which nourishes the outer half of the cortex and is least important of the three.

A large fragment in a comminuted fracture of the femur, tibia, humerus, or one of the bones of the forearm may be so detached from surrounding soft tissue that nutrient, metaphyseal, and periosteal blood vessels supplying the fragment are separated from it (Fig. 1). In such cases, the segmental fragment and sometimes the ends of the two major fragments are so devitalized that they are in the same situation as a full-thickness autogenous bone graft (Fig. 2). Axhausen and Bergmann showed that some bone cells attached to the periosteum and at least some endosteum of bone transplants survive and take active part in generating new bone. As is true of the bone graft, most of the bone cells of a large fracture fragment die. Active hyperaemia of adjacent bone and soft tissue follows the injury. Some peripheral or superficial bone cells survive. Other adjacent bone tissues become active. A vascular fibrous stroma invades the necrotic bone and aids in absorption

There are large phagocytic cells which resorb dead marrow. This resorption by invasion of phagocytes and fibrous tissue is followed by bone formation. Both processes are going on at the same time. This transformation is very slow and may require years until new bone with Haversian canals and red bone marrow has replaced the old necrotic bone and the intervening callus (Fig. 3).

Phemister [9, 10] has most accurately described this method of bone absorption and replacement; he termed "creeping substitution" the process which Axhausen had previously called *schleichender Ersatz*. In all instances of aseptic necrosis, union of the fracture will be delayed and complete healing with recanalization must await replacement of devitalized bone by creeping substitution.

FIG. 3

Photomicrograph (× 50) of bone from the major fracture fragments of a humerus with non-union, six months after injury. The dead bone shown in this section is undergoing absorption and replacement by creeping substitution.

Phemister, in 1930, discussed aseptic necrosis following interference with blood supply in fractures of the neck of the femur, the body of the talus, the calcaneus, and in bone transplants. Cornil and Coudray reported as early as 1904 that, in experimental fractures, necrosis of the cortex is present for a variable distance from the fragment ends. This zone of necrosis is replaced slowly by bone growing in from the living cortex, with which it is continuous, and to some extent from the adjacent callus. The process of healing of a fracture takes place simultaneously with the transformation by creeping substitution of the necrotic bone to new living bone. Leriche and Policard were of the opinion that the calcium used in the formation of callus came for the most part from the aseptic necrotic bone at the ends of the fracture fragments.

The bone which is necrotic retains a density greater than that of the living adjacent bone. This is so recognized in roentgenograms that are made after sufficient time has elapsed to permit atrophy of the bone which has retained a good blood supply. This relative difference in density is produced by the fact that the living bone atrophies following the fracture, while the bone which is deprived of its vascularity is unable to atrophy, having insufficient blood supply to take away the opaque mineral salts.

The following case reports demonstrate the typical course of a segmental fracture of a major long bone.

CASE 1 J L, a male, aged fifty-three years, suffered a severe crushing injury to both legs on December 9, 1946 The fracture in the right leg was segmental, with a large, full-thickness fragment of tibia which included part of the proximal third and most of the middle third of the shaft (Fig 4-A) This fracture was reduced accurately and internal fixation was secured with metal plates and screws Eight months later, on July 24, 1947, there was very little evidence of union Union was satisfactory by March 25, 1948, fifteen months after the fracture However, the large segmental central fragment, which had never been completely detached from the surrounding soft tissue, still retained almost the same density that was present on the day of the accident (Fig 4-B)

A more comminuted fracture with smaller fragments was sustained in the upper third of the left tibia These fragments were adjusted for position, and fixation was maintained with a metal plate Eight months after the injuries, the fractures in this leg were united

These fragments were small and in contact with vascular soft tissue, and they either retained enough blood supply, by way of nutrient or periosteal blood vessels, to survive, or were rapidly transformed by creeping substitution to new bone of relatively normal density

CASE 2 J H, a male, aged forty years, suffered a complex simple fracture of the middle third of the right femur on May 31, 1946, when a large slab of concrete fell, striking him on the right thigh A massive medial fragment of the femur was completely displaced from contact with the proximal and distal portions of the femoral shaft (Fig 5-A) Although this was replaced at operation without detachment of the soft parts, it failed to undergo atrophy, but retained the density which we recognize in the roentgenograms as that of aseptic necrotic bone This delayed, but did not prevent, union Roentgenograms taken on January 17, 1947, seven months after fracture, showed that union was progressing slowly (Fig 5-B)

FIG 4-A

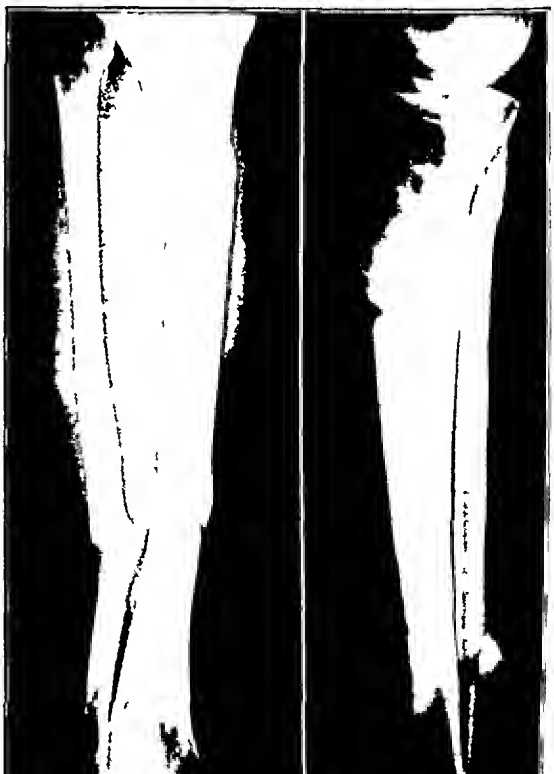


FIG 4-B

Fig 4-A Case 1 These roentgenograms show a fracture of the right tibia with a detached fragment, representing more than the middle third and including the complete cortical circumference in one segment It is a reasonable conclusion that the nutrient artery was either ruptured or entered the tibia above the proximal break, and that the middle fracture segment was nourished only by periosteal vessels

Fig 4-B Fifteen months after injury, union has taken place The segmental fragment, however, has retained greater density than have the metaphyseal fragments, indicating aseptic necrosis Although union has occurred, the fracture ends of the metaphyseal fragments are also of greater relative density than bone more distal to the fracture sites

Fig 5-A

Fig 5-B

Fig 5-A Case 2 Roentgenogram of the right femur, showing a segmental fracture which occurred May 31, 1946

Fig 5-B Seven months after fracture, there is evidence of aseptic necrosis and delayed union

Fig 6-A

Fig 6-B

Fig 6-A Case 3 Roentgenograms of simple segmental fractures of the right tibia and fibula An open reduction was performed April 16, 1946, care being taken to avoid more stripping of the fragments than was absolutely necessary

Fig 6-B Adequate union was present six months after fracture There is less evidence of aseptic necrosis here than was illustrated for Case 1 The possibility that the nutrient artery may have still been intact and supplying the middle or segmental fragment would seem to be a reasonable conclusion

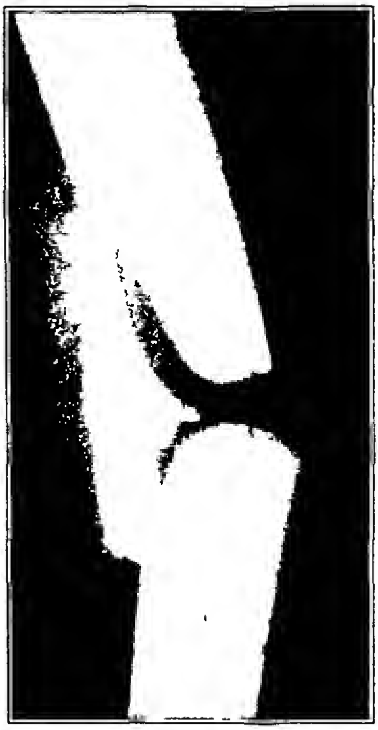


FIG 7-A

FIG 7-B

Fig 7-A Case 4 Fracture of the humerus with a fragment which includes only about one-third of the total cortical circumference

Fig 7-B Union with good alignment, three months after fracture, treatment was by hanging cast The density of the fragment is similar to that of the adjacent cortex The prognosis for survival of the more superficial osteoblasts in a small fragment is more favorable than for the segments which include a complete circumferential cortical fragment

CASE 3 A C, a male, aged fifty seven, was admitted to Chicago Memorial Hospital on March 16, 1946, because of multiple injuries, including large segmental fractures of the tibia and fibula, without compounding (Fig 6-A) The fracture fragments were aligned and immobilized by open reduction and internal fixation on April 16 Approximately five months after reduction, on September 13, roentgenograms showed evidence of bony union (Fig 6-B) The patient was discharged from care with recovery of strength and function of the extremity, April 9, 1947, thirteen months from the time of injury The large segmental fragment showed atrophy to a greater extent than did a similar fragment in Case 1

The probability that an intact nutrient artery may have supplied this middle fragment was suggested by the favorable course of healing and by the fact that the retained density was less than would be compatible with a diagnosis of total aseptic necrosis

CASE 4 O B, a woman, aged forty-seven, was admitted to Chicago Memorial Hospital on January 27, 1948, because of an injury to the left arm Roentgenograms showed a butterfly type of fracture of the middle third of the humerus The separate middle fragment included only about one-third of the circumference of the shaft of the humerus and hence exposed a considerable amount of cancellous tissue to the serum, which is the ideal tissue-culture media (Fig 7-A) This patient was treated with a hanging cast, and on April 23, three months after the injury, the fracture was united with abundant callus (Fig 7-B)

It would appear to be a reasonable assumption that the medullary bone and the more superficially placed osteoblasts of the cortical fragment survived and took part in the healing of the fracture The prognosis for survival of the detached fragment in a segmental fracture is more favorable when the fragment is small

CASE 5 A M, a woman, aged sixty-nine, was admitted to the Chicago Memorial Hospital * on July 19, 1947, because of a simple fracture of the lateral condyle of the left femur (Fig 8-A) An open reduction and internal fixation by means of threaded pins and a single large screw were successfully carried out on July 22 (Fig 8-B) Subsequent roentgenograms showed evidence of marked reduction in blood supply of the condylar fragment, indicated by failure of the bone to become atrophied, as did the adjacent femoral shaft and the medial condyle However, approximately fourteen weeks after the injury, roentgenograms showed what appeared to be union of the fracture (Fig 8-C) The patient was permitted to bear weight Subsequent roentgenograms showed refracture and upward displacement of this lateral condyle (Fig 8-D) The retained density of the aseptically necrotic condylar fragment with areas of decreased density representing absorption and replacement with creeping substitution are well illustrated

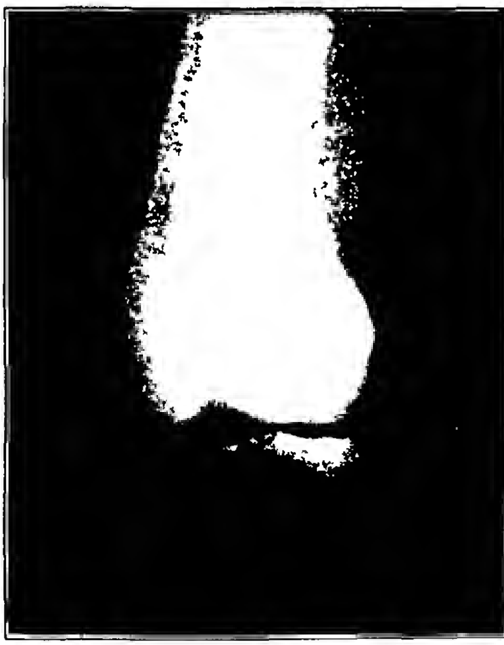
This case demonstrates the importance of considering the possibility of aseptic necrosis in any detached major fragment of a fracture of a long bone Immobilization should be maintained until there is roentgenographic evidence not only of union, but also of replacement of the aseptically necrotic bone by creeping substitution

* Service of Sam W Banks, M D

FIG 8-A

FIG 8-B

Case 5 Illustrating the fate of a large condylar fragment, isolated from the nutrient artery Open reduction may have stripped away some of the remaining periosteal and metaphyseal vessels



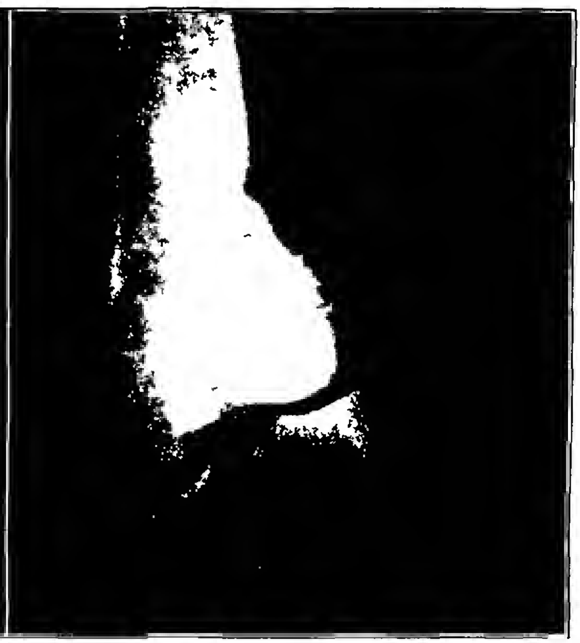


FIG 8-C

FIG 8-D

Fig 8-C This roentgenogram shows evidence of union, fourteen weeks after fracture, but the lateral condyle has retained the density that is typical of aseptic necrosis

Fig 8-D When the patient attempted to walk, refracture occurred (Courtesy of Sam W Banks, M D)

COMMENT

With reasonable certainty we may predict a marked delay in union of large segmental fractures of the mid-shaft or ends of a major long bone The larger the separate fragment in a segmental fracture in a long bone, the poorer the prognosis from the standpoint of

viability of that fragment In the event that a fragment is partially devitalized and doe not retain enough intact blood vessels to maintain a reasonable exchange of arterial an venous blood, some of the bone cells will die If most of these cells die, the fragment wi become necrotic, although massive sequestration does not occur Union may then b delayed for many months With good fixation, however, healing of the fracture will tak place before the large fragment has undergone complete replacement by creepin substitution

If a principal nutrient artery remains uninjured and supplies the large segmenta fragment, aseptic necrosis may not occur, and the prognosis for undelayed healing of th fracture is good

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DISCUSSION

Slipped Capital Femoral Epiphysis

(*Continued from page 22*)

the epiphysis, but also to put two grafts across the outside I think a graft through the center of the epi physeal line cannot be depended upon to cause fusion of the epiphysis

Finally, I think these hips should be fixed with a Smith-Petersen nail just as early as the slipping can be demonstrated I think they ought to be permitted to slip a little, otherwise hips will be nailed that may not have slipped Just as soon as the diagnosis can be made, they should be nailed You should not depend upon walking with crutches to prevent slipping In the past two years, I have seen slipping occur in two hips while the patients were using crutches, both of them had slipped to a point where I thought I had to nail the hip, with resulting moderate deformity I was afraid to take off the head because I had seen aseptic necrosis occur in two cases It is quite difficult to get a bone peg in position

I think in putting the nail in after the hip has begun to slip, you should put it as far posterior in the neck as possible I notice that some of these nails just reached the top of the epiphyseal line The nail should extend well into and fix the head

TREATMENT OF THE NECROTIC HEAD OF THE FEMUR IN ADULTS *

BY DALLAS B. PHEMISTER, M.D., CHICAGO, ILLINOIS

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With the recent advance in knowledge of injuries and diseases of the hip—and especially with the great increase in the incidence of bony union following pinning and wiring of fresh fractures—aseptic or avascular necrosis of the head of the femur has come to be recognized as one of the most important and perplexing problems which confront the orthopaedic surgeon. Although aseptic necrotic lesions in adults are similar to those of childhood and adolescence, the differences are sufficiently great, particularly with reference to spontaneous repair and treatment, to require separate consideration.

Aseptic necrosis of the head of the femur in adults results from interruption of the circulation by either physical injury or non-traumatic occlusion of its blood vessels[3, 11, 12], injury being a more frequent cause than occlusion. Of the physical injuries producing aseptic necrosis of the head, fractures of the neck of the femur comprise the great majority, the remainder being dislocations and plastic operations designed to restore mobility of the hip joint. Of the non-traumatic lesions producing necrosis by occlusion of the vessels of the head, the one best known is caisson disease; in this condition, nitrogen gas, liberated from the blood and tissue fluids by too rapid decompression, somehow obstructs the circulation, either by embolism or by compression of the vessels of the bone by gas within its medullary tissues. The head of the femur is usually involved in multiple infarction of the epiphyses and diaphyses of the large bones. The other obstructing vascular lesions are more obscure and difficult to identify, but must result from embolism, thrombosis, or obliterating vascular diseases. They produce similar necrosis in the head of the femur, either alone or in association with infarcts of other parts of the skeleton.

Interruption of the blood supply to the head of the femur in adults causes death both of the bone and of the overlying articular cartilage, whereas in children all or most of the cartilage survives by nourishment derived from the synovial fluid. Such interruption of the blood supply may impair the hip joint by increasing the frequency of non-union of fracture of the femoral neck (if that is the cause of interruption of the capital blood supply), by production of pathological fracture and of collapse and disintegration of varying amounts of the weight-bearing necrotic portion of the head, and by causing late degenerative arthritis of the hip.

In general, a fracture of the neck of the femur unites more frequently if the head remains alive. This is because there is callus formation from the end of each fragment when the head survives, but only from the end of the distal fragment when the proximal or head fragment dies. In a series of forty-nine cases[10], studied before the efficient modern techniques for obtaining bony union by pin, threaded wire, or screw fixation of the fresh fracture were in common use, non-union was observed four times as frequently when the head died as when it remained alive. Some degree of degenerative arthritis usually develops in the hip joint, independently of whether or not an associated fracture of the neck unites or the dead head collapses. With improved methods of reducing and fixing fresh fractures by means of nails, screws, and threaded wires, bony union is obtained in the majority of cases in which the head fragment has been killed at the time of fracture by tearing of its blood vessels[4]. Collapse of a portion of the necrotic head of the femur takes place as a result of pressure upon it from the acetabulum. This does not occur if the fracture of the neck remains ununited, since then the head cannot bear sufficient weight, but a gradual invasion

* Read at the Joint Meeting of The American Orthopaedic Association, The British Orthopaedic Association, and The Canadian Orthopaedic Association, Quebec, Canada, June 3, 1948.

FIG 1-A

FIG 1-B

Fig 1-A Case 1 Fracture of neck of femur and necrosis of head of nine months' duration Non-union of fracture and partial replacement of lower portion of head by new bone of low density Inset shows roentgenogram of slice of a similar dead head confirmed by microscopic examination
Fig 1-B One week after operation

of such a necrotic head by blood vessels and osteogenic tissue usually occurs by way of untorn portions of capsule, the round ligament, and adhesions, and a variable amount of the dead bone becomes replaced by a less dense disuse type of new bone During the first *two or three years the head is usually so well preserved that operative treatment and* proper postoperative protection may bring about bony union of the fracture fragments replacement of the dead tissues by living tissues without collapse, and a good functional result

Using Compere and Lee's technique of open reduction of the ununited fracture and fixation by two tibial bone grafts and threaded wires, the author placed the drill holes and inserted the rectangular pegs into the necrotic upper half of the head of the femur in Case 1 The patient was operated upon nine years ago

CASE 1 H A , a woman, fifty-two years old, had had an ununited fracture of the neck of the left femur for nine months Roentgenographically, the upper portion of the head possessed an even density which was slightly greater than that of the atrophic bone of the trochanteric regions Most of the lower portion of the head showed marked blotchy reduction in density (Fig 1-A) A diagnosis was made of death of the head with blotchy revascularization and replacement of its lower portion by fine spongy new bone The picture is somewhat similar to that of the inset on Figure 1-A, which shows a roentgenogram of a slice of dead head excised in a case of non-union of ten months' duration Microscopically, the dense area above and laterally consisted of old dead bone, and the rarefied inferior portion had been replaced by finely trabeculated new bone

Through a Smith-Petersen incision, the fracture was reduced and two one-centimeter drill holes were made to converge from the side of the shaft through the neck and deep into the remaining upper portion of the head One was placed just beneath the articular cortex of the upper portions of the neck and head The drill removed a proportionately large amount of the remaining necrotic head Rectangular tibial bone grafts were inserted into the drill holes, they acted as struts to prevent collapse of the head and to bridge the fracture line The remaining space in the drill holes permitted upward growth of callus from the neck into the head, with invasion of the remaining dead bone and replacement by new bone The three threaded wires, inserted through the head and neck, gave additional fixation of the fracture (Fig 1-B)

A roentgenogram at the end of two months revealed evidence of bony union of the fracture fragments (Fig 1-C) The patient continued to walk on crutches until eight months after the operation, at which time a roentgenogram revealed extensive reconstruction of the upper portion of the head (Fig 1-D) The threaded wires were then removed, since one of them projected into the joint Walking was resumed with no discomfort, and there was a good return of function There was roentgenographic evidence of progressive replacement at ten months (Fig 1-E), thirteen months after operation the upper portion of the head was

Fig 1-C

Fig 1-D

Fig 1-C Two and three-quarters months after operation
Fig 1-D Eight months after operation

Fig 1-E

Fig 1-F

Fig 1-E Ten months after operation fracture has united and head shows extensive reconstruction
Fig 1-F Seven and one-half years after operation, the roentgenogram shows reconstruction of the head without collapse, there is a minimal degree of arthritis Function is excellent

normal in contour and, except for parts of the grafts, appeared to have been entirely reconstructed From that time onward the function of the hip joint was normal, aside from very slight limitation of flexion, a roentgenogram taken seven and one-half years after the first operation revealed a similar appearance, with no collapse of the weight-bearing portion and with minimal arthritic changes in the joint (Fig 1-F)

The evidence indicates, first, that the drilling not only removed much of the dead bone, but also permitted rapid invasion and transformation of that which remained in the upper portion of the head, and, second, that the bone pegs served to prevent fracture and collapse of the head as well as to facilitate union of the fracture

Bone-drilling and bone-pegging operations have usually been done primarily to obtain

bony union of the fracture [1, 2], whether fresh or ununited, and the grafts have most frequently been placed roughly in the central portion of the head, whether it is dead or alive Both threaded wires and pins and nails, as the Smith-Petersen type [7], have been used for additional fixation of the fracture A cursory review of roentgenographic illustrations of some of the published cases reveals that, when the head is dead, it sometimes becomes transformed after bony union and does not collapse, while in other instances, probably more frequently, it collapses and a poor result is obtained Since the excellent long-term result observed in Case 1, previously reported by Sherman and Phemister, three additional patients with non-union, necrosis of the head, and erosion of the neck have been operated upon within the past thirteen months by the insertion of a single graft and three threaded

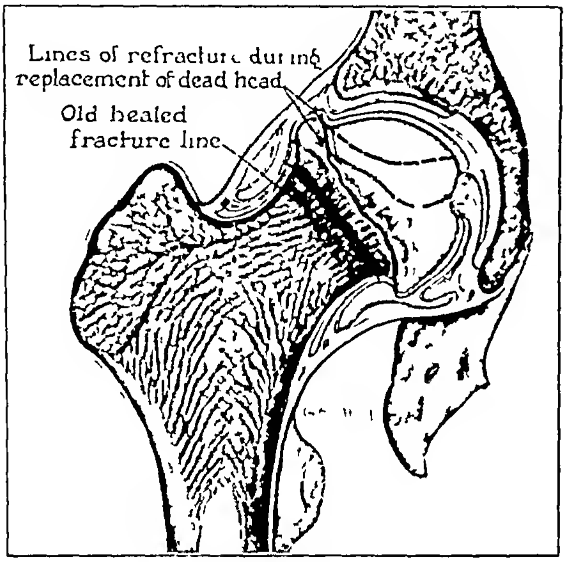

FIG 2

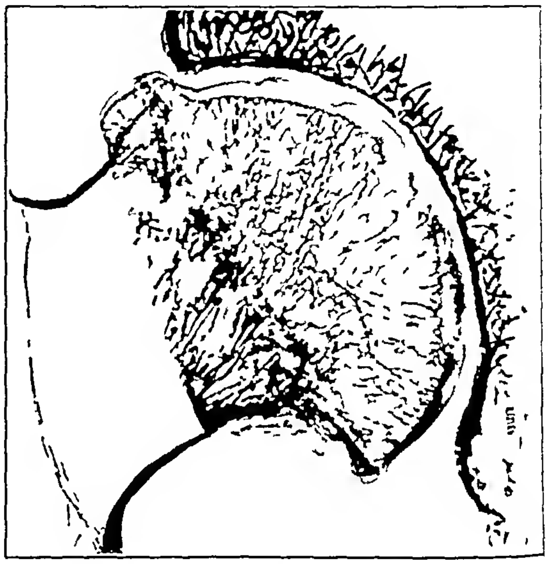

FIG 3

Fig 2 Sketch of healed fracture of neck and necrosis of head fragment with refracture and collapse from weight-bearing when the weak part of the zone of creeping substitution reaches the upper margin of the head, beneath the lateral margin of the acetabulum The downward and medialward course of the fracture line varies with the extent of invasion of the lower portion, as indicated by the lines The line nearest the neck has been sketched from Fig 3

Fig 3 Microscopic section of excised dead head and proximal portion of neck, including old subcapital fracture site (Case 5 of Sherman and Phemister) Refracture and displacement through zone of replacement of head, extending from beneath margin of acetabulum above to margin of articular cartilage below (nineteen months after injury)

wires into the central and upper regions of the head The fracture has united in all cases and there has been extensive invasion and transformation of the head, but the time has been too short for the end results to be known

In drilling operations alone [5, 8], performed for enhancing bony union and for replacement of dead bone, the multiple drill holes have been more or less evenly distributed within the head and neck

If non-union persists for three or more years, the dead head frequently becomes so extensively disintegrated and adherent that bony union of the fracture and good hip function cannot be obtained by operation Treatment of such neglected cases should usually be by excision of the head and the performance of some type of plastic reconstruction operation [9, 14], or by ankylosis of the hip

The treatment of aseptic necrosis of the head of the femur, in cases in which the neck is intact, may be approached in a manner similar to that which has just been described for ununited fracture of the neck of the femur with necrosis of the head This includes cases in which the neck has been fractured and has undergone bony union, as well as those in which the necrosis was caused by dislocation of the hip or by vascular occlusion If the hip is protected for the first two or more years by avoidance of weight-bearing, the head may be

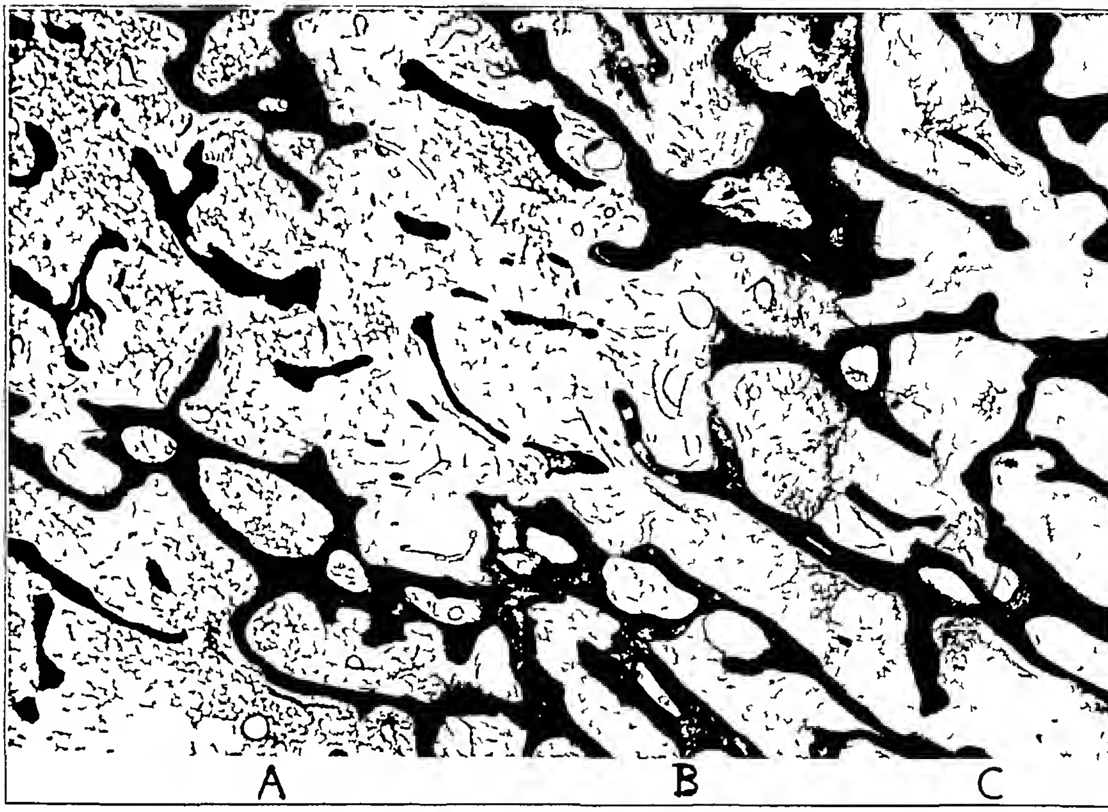

Fig 4

Photomicrograph (× 12) shows zone of creeping substitution of dead bone of head by new bone in a case of ununited fracture of neck of femur of eight months' duration

A Creeping substitution of dead trabeculae by temporarily weaker new trabeculae, and differentiation into fatty and hemopoietic marrow

B Creeping invasion of fibrous callus

C Dead bone and dead marrow Trabeculae larger than those in Zone *A*

ivaded and replaced by new bone without change in contour Such abstinence from eight-bearing is rare, however, and there is subsequent fracture of the head in the great ajority of cases, with more or less collapse and disintegration of the broken-off necrotic ortion The patient usually walks with little or no difficulty for six to eighteen months fter the occurrence of the necrosis During this time it is usually difficult to diagnose the resence of necrosis roentgenographically, because the contour of the head is normal and here is little difference in density between the dead bone of the head and the neighboring ving bone which, being used in weight-bearing, shows little atrophy of disuse Then radually increasing pain, weakness, and stiffness in the hip are experienced, a roentgenoram shows fracture and beginning collapse of the weight-bearing portion of the head and nore definite reduction in density of the living bone of the trochanters, resulting from lisuse

Usually the fracture and collapse occur when the slow process of invasion, absorption, ind substitution of new bone from the neck approaches or reaches the lateral margin of he upper portion of the head, this portion is in contact with the acetabulum, and the iew bone receives the weight transmitted from it The damage occurs here because the iewly formed bone in the zone of creeping substitution is, for many days, weaker than the ıld dead bone which it has replaced, and it will not withstand weight-bearing during that ieriod This occurrence, which is appreciated all too little, is the crux of the collapse probem The narrow zone of new bone is fractured and the remaining dead bone is displaced lownward by pressure from the acetabulum Fracture and collapse may happen after varying degrees of invasion and replacement of the lower portion of the head (Fig 2) Occasionally the fracture line and the displacement run downward through the head, from

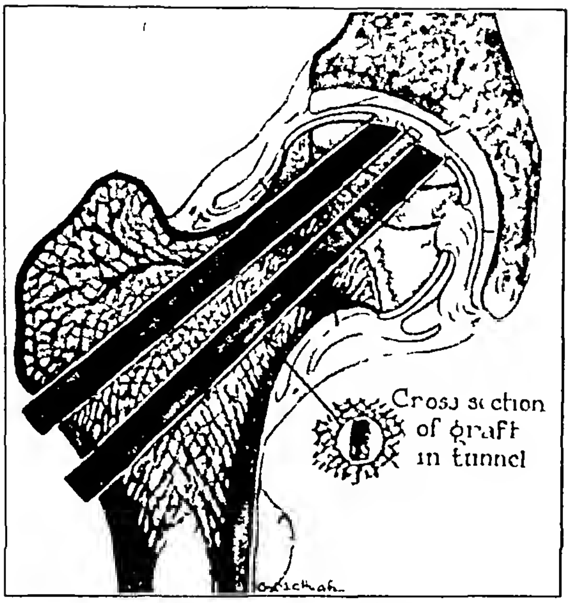

Fig. 5

Sketch of drilling and pegging of necrotic head in various stages. Ingrowths from neck alongside the grafts and from round ligament help to replace dead bone and cartilage.

the acetabular margin at the upper limit to the junction of the head and neck on the undersurface. This is shown by the unbroken line of Figure 2, which was sketched from the microscopic section shown in Figure 3. Usually there is more rapid invasion in the lower region than in the upper, and the line curves medially and terminates about the level of the fovea or more frequently, somewhat higher.

Figure 3 shows a microscopic section of the head and proximal portion of the neck of the femur, excised nineteen months after an impacted subcapital fracture, which caused necrosis of the proximal fragment and was followed by bony union. The invasion and replacement by new bone had recently reached the top of the head at the acetabular margin and had extended downward into the margin of the head below. A fracture had occurred through the narrow zone of weak new bone in the zone of creeping substitution, and the dead portion of the head had collapsed from pressure against the acetabulum. Microscopic examination, previously reported[13], revealed necrosis of both bone and cartilage in the head, proximal to the new fracture line, except for some invasion from the fovea and replacement of some of the articular cartilage inferior to it by new bone and marrow. The dead cartilage over the living bone of the top of the head, lateral to the acetabular margin had been replaced by fibrocartilage.

If there is early revascularization and new-bone replacement of the medial and inferior portions of the head, or if the inferior portion is not killed, as in some cases of caisson disease, a bowl-shaped fragment of the upper and central portions may break off. Figure 4 shows a microscopic section of a zone of creeping substitution, through which the patho-

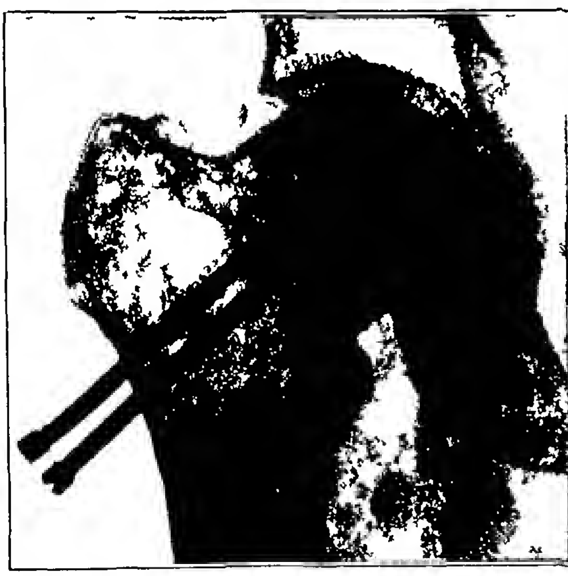

Fig. 6-A

Fig. 6-B

Fig. 6-A. Case 2. Twenty months after primary nailing, fracture has united. Dead head is slightly more uniform and dense than living trochanteric region, which is atrophic from disuse.

Fig. 6-B. Seven months later, pins are working out. Refracture has occurred at junction of head and neck, with slight downward displacement of head. Trochanters are still more atrophic, while head retains former density, indicating that it is dead.

Fig 6-C

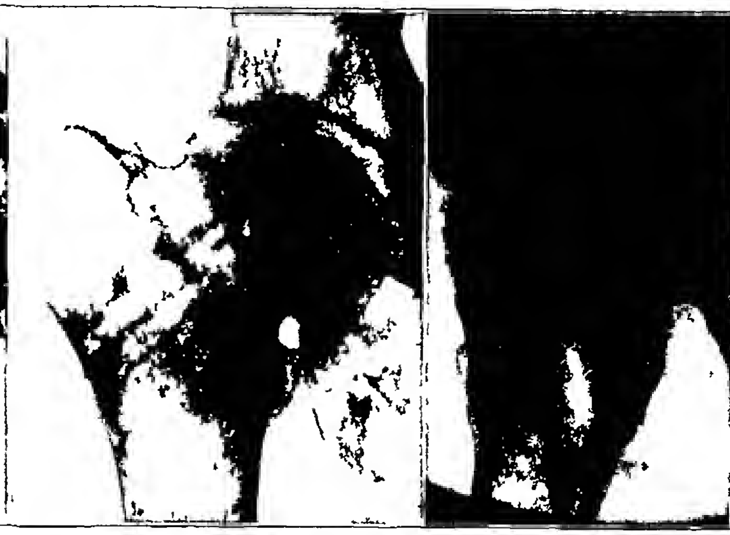

Fig 6-D

Fig 6-C Two months after operation, fracture has united
Fig 6-D Six months after operation, head is extensively transformed

Fig 6-E

Fig 6-F

Fig 6-E Seven and one-half months after operation
Fig 6-F Twelve and one-half months after operation, the head has apparently been replaced by new bone without change in contour

logical fracture takes place if weight is thrown upon it *C* is the dead bone of normal density, *B is the zone of invasion of the cancellous spaces by fibrous callus, and A is the zone* of metaplasia in which the fibrous callus becomes differentiated into cancellous weak new bone and marrow, simultaneously with absorption and replacement of the dead trabeculae

The earliest sign of aseptic necrosis of the head in the presence of an intact femoral neck is usually the beginning downward displacement of the broken-off weight-bearing portion, or in some cases the roentgenographic evidence of greater density of the non-atrophic head as compared with the atrophied living bone of the trochanters

Experience in Case 2 suggests that, as soon as the presence of necrosis of the head of the femur can be established in this group, drilling and bone-grafting should be carried out in a manner similar to that practised in the case of ununited fracture of the neck and necrosis with little disorganization of the head, and, if performed before there is downward displacement and erosion of the broken-off portion, a successful outcome should be obtained

CASE 2. E. M., a woman, sixty years old, sustained a fracture of the neck of the right femur, the line passing upward and outward from just distal to the mid-portion of the inferior cortex to the superior cortex near its junction with the head. The fracture was treated initially by closed reduction and fixation with steel nails, bony union followed. The patient walked with two crutches for about a year, and then with a crutch and cane. The hip was mobile and almost painless, but weak, at the end of twenty months. At that time a roentgenogram (Fig. 6-A) revealed a shortened neck, impacted below, and bony union of the fracture. There was reconstruction of the lower portion of the proximal fragment of the neck and a uniform shadow of most of the head of the femur, which was slightly more dense than that of the adjacent atrophic living bone of the trochanteric regions. These findings were indicative of an unreplaced necrotic head and of replacement of the necrotic head fragment of the neck by new bone, invading across the healed fracture. Walking with a crutch was continued, but the hip soon became painful and weak, and the use of two crutches was resumed. A roentgenogram taken seven months later (Fig. 6-B) revealed evidence of an irregular line of pathological fracture, extending downward through the lateral margin of the articular surface of the head, lying beneath the acetabular margin above, to the junction of the head and neck below. There had been loosening and slight extrusion of the pins and slight downward displacement of the dead head. The shadow of the trochanteric regions was more reduced in density, since it had undergone further disuse atrophy, while the density of the head was unchanged. The fracture had taken place through the zone of invasion and replacement of the dead fragment by new bone, when its upper portion reached the margin of the acetabulum and weight fell upon it.

At operation, the pins were driven deeper into the head, and two holes were drilled through it with a one-centimeter drill, one being beneath the pins and the other above, each penetrated the head and extended into the joint. Rectangular bone grafts, taken from the opposite tibia, were inserted into the holes. The upper pin and graft extended across the joint and were withdrawn to just within the head. It was possible for fibrous callus to grow alongside the rectangular grafts in the drill holes, across the line of pathological fracture, and to invade and replace the remaining dead bone by new bone, and for fibrous tissue to grow out onto the articular cartilage, which becomes absorbed and replaced by fibrocartilage. This is shown as part of a composite sketch (Fig. 5).

Roentgenograms taken two months and six months after operation (Figs. 6-C and 6-D) show evidence of bony union of the fracture, and subsequent roentgenograms up to twelve and one-half months after operation (Figs. 6-E and 6-F), reveal a gradual replacement of all dead bone by new bone without change in contour of the head. The hip is painless, motion is almost normal, and partial weight-bearing has recently been resumed.*

The result obtained is thus far similar to that in Case 1, and the two cases indicate that the operative procedure is based upon sound principles.

FIG. 7-A FIG. 7-B

Fig. 7-A. Case 3. Twenty-five months after fracture, limb was being used in walking and little difference in density was apparent between head and trochanters.

Fig. 7-B. Four and one-half months after drilling, pegging, and re-nailing. Fracture has united, although line was not exposed or callus cleaned out. Upper tibial graft does not enter top of head.

* Seventeen months after operation, the contour of the head was still intact.

In Case 3, with ununited fracture of the neck and death of the head, the upper graft was carried across the ununited fracture line to the margin of the superior portion of the head, while the lower graft penetrated the head deeply The fracture united, but the top of the undrilled and unpegged head broke down after sixteen months, and an unsatisfactory result has been obtained

Case 3 F S, a woman, sixty-six years old, had a subcapital fracture of the neck of the right femur Treatment was by open reduction, fixation with three threaded wires placed close together, and onlay chips from the ilium across the fracture line Density studies in subsequent roentgenograms indicated death of the head Non-union resulted, and the neck gradually shortened as a result of erosion of fragments from walking Figure 7-A shows the condition twenty-five months after injury Through a lateral incision, two additional wires were inserted across the neck into the head, after which the three old wires were removed A one-centimeter drill was then inserted along the pathway of the old wires through the head and, as a result of miscal-

Fig 7-C

Fig 7-D

Roentgenograms show union of fracture and progressive transformation of lower portion of head

Fig 7-C Nine and one-half months after operation

Fig 7-D Sixteen and one-half months after operation

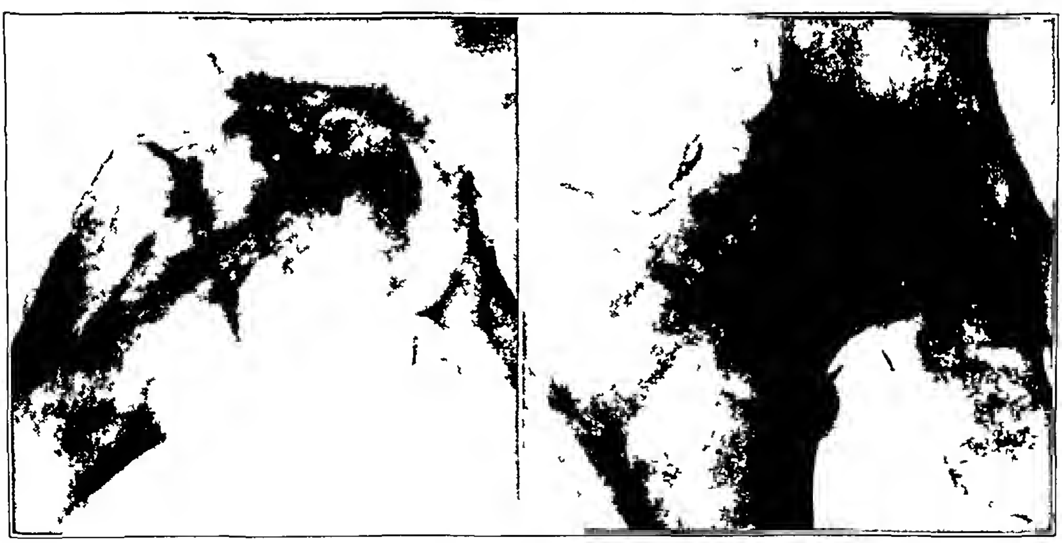

Fig 7-E

Twenty-two months after operation Roentgenograms show breaking down and absorption of top of dead head, into which the upper graft did not extend

culation, for a short distance into the acetabulum. The articular cartilage of the head was thus open to invasion and replacement from the drill hole. A rectangular bone graft from the tibia was inserted deep into the head. A second hole, drilled through the upper portion of the neck, extended for only a short distance into the lateral portion of the head, and a similar bone graft was inserted the length of the hole, barely bridging the fracture line. This left the upper portion of the dead head intact. The fracture united promptly, despite the fact that the fracture line was not exposed or curetted (Fig. 7-B).

The patient walked with a cane after four months, and the wires were removed after eight months. The middle and lower portions of the head were gradually transformed (Fig. 7-C). Fair hip function was regained with relatively little pain, and the contour of the top of the head was normal, sixteen and one-half months after the last operation (Fig. 7-D). Pain and stiffness then developed and the patient soon resumed the use of crutches. The pain continued, and twenty-two months after the second operation, roentgenograms showed breaking down and absorption of the top of the head (Fig. 7-E).

A similar result was recently seen in a patient treated elsewhere by threaded pins and a bone graft inserted through the center of the head. Had drilling and insertion of the bone graft through the entire length of the upper portion of the head been carried out, the result might have been comparable to that obtained in the first two cases.

In the presence of an intact femoral neck, cases of long-standing necrosis of the head with marked collapse, deformity, and degenerative arthritis may require treatment by some type of plastic procedure, such as the Vitallium-cup arthroplasty, or by arthrodesis of the hip.

In cases with persistent dead bone and less extensive deformity, an endeavor may be made to obtain replacement of the necrotic areas by new bone, and improvement in the structure of the head by drilling and bone-pegging procedures directed at the necrotic bone. Two such patients have been operated upon; their histories will be briefly recorded here, although the time elapsed is too short for the end results to be known.

CASE 4. R. Y., a male, aged thirty-one, was admitted to the Clinic three years after he had sustained an intracapsular fracture of the neck of the right femur. Primary fixation of the fracture had been accomplished by means of a Smith-Petersen nail, inserted through the upper portion of the neck and about one-half the length of the head. Bony union followed, and use of the extremity was resumed with almost complete freedom from symptoms. Twenty-nine months after the operation the patient began to have pain, weakness, and stiffness in the right hip, which progressed slowly. A roentgenogram on admission revealed union of the cervical fracture and evidences of transformation of the inferior and lateral portions of the head into new bone. The superior portion of the head, medial to the margin of the acetabulum, was broken off above the point of the nail and was separated by a zone of reduced density, compatible with non-union. It cast a slightly denser shadow than the adjacent transformed bone, and was slightly displaced downward. At operation the nail was removed and the old channel was entered with a one-centimeter drill, which was carried through the detached portion of the head. A second drill hole was made, beginning just below the first hole and being carried slightly backward and upward into the posterior part of the detached portion. Rectangular tibial bone grafts were inserted into the holes. Roentgenograms revealed that the grafts extended across the ununited fracture line, but not through the entire thickness of the necrotic area to the joint surface.

The patient has been kept on crutches for seven months, and series of roentgenograms have shown evidence of bridging of most of the ununited fracture line, but the fragment does not yet appear to be completely replaced by new bone.

CASE 5. F. B., a male, aged thirty-eight years. This patient had been followed for twelve years, because of slowly progressive fibrocystic disease in the head of each femur, more marked in the right, where there was extensive degenerative arthritis. Serial roentgenograms showed what appeared to have been a large area of aseptic necrosis at the top of the right head, overlying a cavity which had caused it to break off. It had organized slowly, but a portion appeared to be still separated by an ununited fracture line. In the past two years, similarly, the thin roof above the cavity in the top of the left femoral head had broken off and appeared to be collapsed and ununited. The left hip was only slightly impaired, but there was marked limitation of motion, moderate pain, and roentgenographic evidence of degenerative arthritis in the right hip.

Five and one-half months ago the left hip was operated upon. Two holes, each one centimeter in diameter, were drilled the length of the neck into the partly sclerotic, partly cystic area of the upper portion of the head, and rectangular tibial bone grafts were inserted almost to the articular cortex. Two weeks later the right hip was operated upon. A hole was drilled the length of the neck only, and aimed at the medial portion of the necrotic ununited fragment at the top of the head. A circular drill was then used and carried through into the joint, thereby obtaining a core of the area for microscopic examination. A second hole was drilled

beginning just below the first and carried through the neck posterior and lateral to the first Again with the circular drill, a core was cut, extending the length of the head into the joint Rectangular tibial pegs were inserted the length of the holes Series of roentgenograms have shown that the grafts have become attached to the broken-off fragment which is undergoing transformation and fusion with the head

The cannulated drills and guide wires and the circular biopsy drills and obturator are shown in Figure 8 The results of biopsy of the head of the femur by this technique will be published in a later report

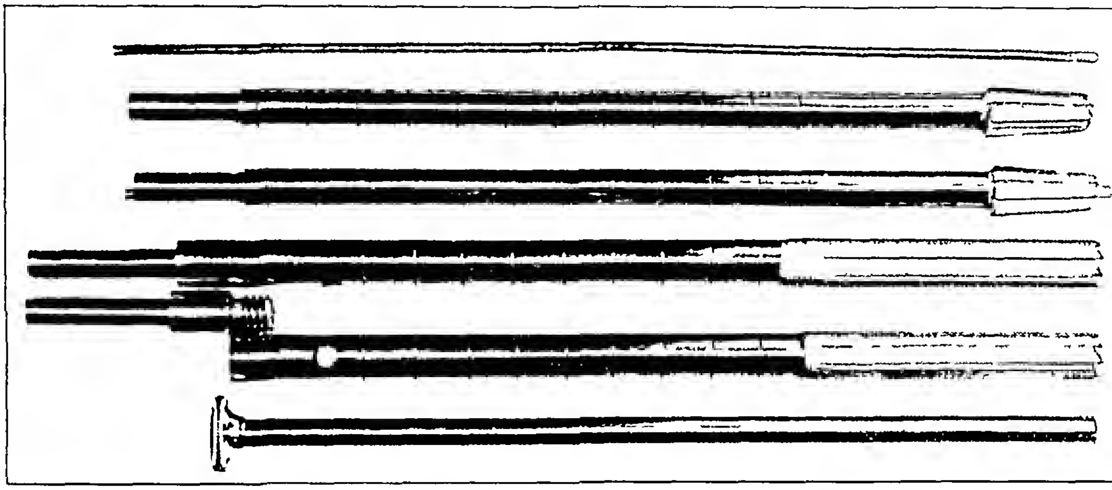

FIG 8

Above, modified Albee drills and guide wires Below, circular drills and obturator for obtaining biopsy specimen from head

SUMMARY AND CONCLUSIONS

Two cases of necrosis of the head of the femur, one associated with an ununited fracture of the neck and the other with an ununited fracture at the junction of the head and neck, which developed after healing of a primary fracture located distally in the neck, were treated by drilling two holes across the neck and upper portion of the head and the insertion of a rectangular tibial bone graft into each hole The fractures united promptly and the upper portion of the head was rapidly invaded and replaced by new bone, thereby avoiding collapse of the head from weight-bearing In one patient, function was restored practically to normal and there was little roentgenographic evidence of degenerative arthritis, seven and one-half years after operation An equally promising result was present in the other patient at the end of twelve and one-half months

In a third case of ununited fracture with death of the head of two years' duration, the lower bone graft was inserted across the fracture line deep into the head, while the upper graft was inserted only to the margin of the upper portion of the head Bony union occurred promptly, but, beginning sixteen months after operation, the upper portion of the head, which had not been drilled and supported by a graft, underwent collapse and absorption, and a poor functional result was obtained

The cases present evidence that drilling and bone-pegging of the upper portion of the necrotic head of the femur which has undergone little or no collapse may increase the rate of transformation of the structure into living bone, shorten the non-weight-bearing period, and decrease the incidence of collapse, deformity, degenerative arthritis, and poor functional results

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DISCUSSION

CONGENITAL PSEUDARTHROSIS

(*Continued from page 39*)

splint These were young children, most of whom had had one or more previous grafting operations In three months all had solid bony union with a large amount of external callus

Dr Trueta's explanation of this was essentially as follows The lesion is the site of a constant deforming tension of the posterior soft tissues, which introduces a disturbance of immobilization before a graft alone or new-bone formation can be strong enough to withstand it He believed that the entire bone length of the intramedullary splint, obtained without stenosis of the medullary circulation, allows such complete immobilization as to permit normal callus formation to develop to effective maturity

It seemed to me that this theory and the results secured confirmed the value of external immobilization in the achievement of Dr Moore's brilliant and promising results in this otherwise discouraging condition

DR JOHN R MOORE (closing) I wish to thank the discussors for their valuable contribution to this paper

I would like to emphasize two points which are deemed vitally essential to the success of the method presented First, primary fixation, including pins and plaster, must be maintained until the continuity of the medullary cavity has been restored, which may require from six to nine months or longer The tibial and fibular shafts do not have sufficient strength to withstand the normal physical stresses until the medullary cavity has reformed The second point is the necessity of reinforcing the site or sites of the osteosynthesis, if narrowing or bending is taking place, in order to prevent refracture Common sense demands that this be done before the fracture occurs, and not afterward

The presence of increased alkaline phosphatase in the delayed graft, in the three or four cases analyzed, is believed to be further evidence that immature bone is being transplanted

Dr Peabody's mention of Dr Trueta's work is interesting I am quite sure that fixation is very important

Dr Phemister called attention to the importance of doing control operations with this same type of fixation That, too, is important

Dr Green has covered thoroughly the basis of the problem, and I agree with his conclusion that further study is necessary

INTRACAPSULAR FRACTURES OF THE FEMUR TREATED WITH A COMBINED SMITH-PETERSEN NAIL AND FIBULAR GRAFT*

BY JAMES PATRICK, F.R.C.S., GLASGOW, SCOTLAND

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In 1941, two important papers were published on the results of the treatment of intracapsular fracture of the neck of the femur with the Smith-Petersen nail. One paper was prepared by the Fracture Committee of The American Academy of Orthopaedic Surgeons and dealt with 144 cases fixed with a trifin nail alone, as well as with cases treated by other forms of fixation. The second paper, by Eyre-Brook and Pridie, assessed the results in fifty-two patients treated with a trifin nail. The figures given in each paper were similar,—only some 70 per cent. of cases achieved bony union. Each series was based on a minimum follow-up period of one year. Had a longer minimum period been taken, the figures for aseptic necrosis would undoubtedly have been larger; but as it was, these results showed that the use of a trifin nail alone was far from being the ideal treatment of intracapsular fractures.

It was shortly after the publication of these two papers that the author began to treat all intracapsular fractures with a Smith-Petersen nail and a fibular graft, and since the beginning of 1942, 107 such cases have been thus treated in the Orthopaedic Department of the Glasgow Royal Infirmary.

The complete fixation afforded initially by a trifin nail depends on the physical pressure exerted between the nail and the bone into which it is driven. Only in dead bone are this pressure and fixation maintained for any length of time. Normal vascular bone reacts to physical pressure by local absorption of the bone, and this occurs no matter how inert the metal is, although ionizable material certainly accelerates this reaction. It is for this reason that the nail loses its firm grip within a few weeks of operation. When a graft is added it provides only an imperfect degree of fixation at first, but it soon fuses with the surrounding bone, and thus the complete immobilization of the fracture is maintained.

The fibula was chosen as the source of the graft, because of its strong tubular shape and because it has less dense cortical bone in its structure than has a tibial graft. In old people, regeneration of the fibula does not occur, but the absence of six inches of the fibula appears to cause no disability, whereas removal of a similar length of graft from the cortex of the tibia is often followed by pain and tenderness for many months and the defect left may predispose to fracture of the tibia.

Previous papers have referred to the use of a combined nail and fibular graft in intracapsular fractures of the neck of the femur, but generally only in cases of non-union. King, however, referred in 1939 to the fact that he had begun to use the combined nail and graft in all cases.

TECHNIQUE OF OPERATION

Preoperative Treatment

Prior to operation the lower extremity is immobilized with sandbags, and no traction or other attempt at reducing the fracture is carried out. A spinal anaesthetic of 5 per cent. procaine is invariably employed, and in old patients no preoperative sedative is used. Elderly people rarely, if ever, have headache following a spinal anaesthetic and they are seldom apprehensive. The giving of morphine to them before spinal anaesthesia may precipitate collapse.

The patient is placed on an orthopaedic table and reduction of the fracture is ob-

* Read at the Joint Meeting of The American Orthopaedic Association, The British Orthopaedic Association, and The Canadian Orthopaedic Association, Quebec, Canada, June 3, 1948.

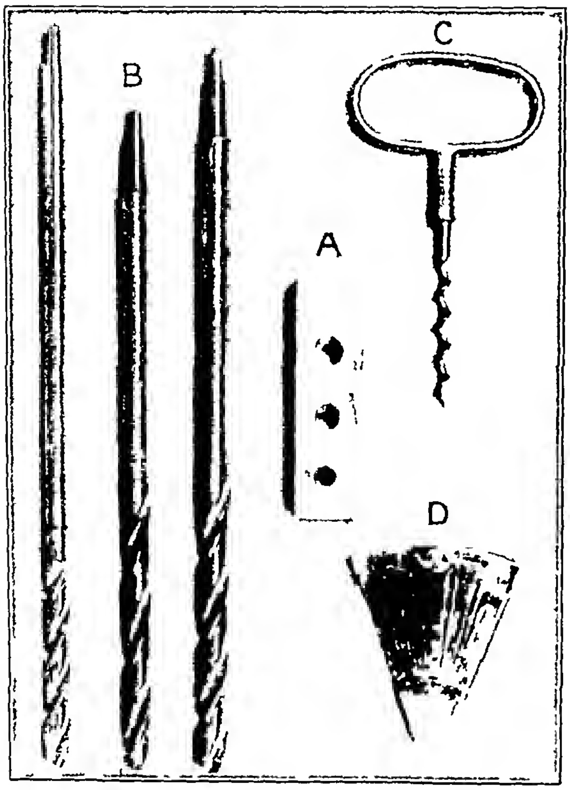

FIG 1

Special Instruments used in Operation
A Perspex gauge, three-quarters of an inch thick, with three holes, one-half inch, seven-sixteenths of an inch, and three-eighths of an inch, respectively, in diameter (Each hole is actually one thirty-second of an inch wider than this)
B Three long-shanked drills, one-half inch, seven-sixteenths of an inch, and three-eighths of an inch in diameter, respectively The slightly wider gauge holes ensure a firm fit for the fibular graft in the drill holes
C Corkscrew which grips lumen of fibular graft well and may be used for withdrawing the graft
D Author's director A simple and cheap instrument, similar in principle to the Engel-May model

tained by slight traction and full internal rotation of the limb Occasionally the Leadbetter method of reduction has been employed, where good reduction could not otherwise have been obtained

Operation

The trifin nail is inserted in much the same way as is generally employed when the nail is used alone, but a greater degree of accuracy is demanded in order to leave room for the graft In the first few cases the graft was placed below the nail, but as it proved technically easier to insert the graft above, this procedure was adopted in all subsequent cases

After the patient is fixed on the table, anteroposterior and lateral roentgenograms are taken to assess the accuracy of the reduction and to determine the precise point of entry of the guide wire through the cortex From the roentgenogram an assistant calculates the distance of this point from the ridge at the base of the greater trochanter to which the vastus lateralis is attached,—this attachment being, of course, the chief landmark in the operation A halfpenny may be held against the trochanter when the preliminary anteroposterior roentgenogram is taken The coin measures exactly one inch in diameter, and no matter how it is held, its shadow on the film gives an index of the degree of magnification which has to be allowed for in any measurement

The calculated distance of the cortical hole from the trochanteric ridge is measured with calipers, and a triangular hole in the cortex of the femur is made This hole is made toward the front or back of the shaft, depending on the degree of anteversion of the neck as determined by inspection of the lateral roentgenogram After the guide wire has been inserted low in the neck, the trifin nail is driven in according to the usual manner

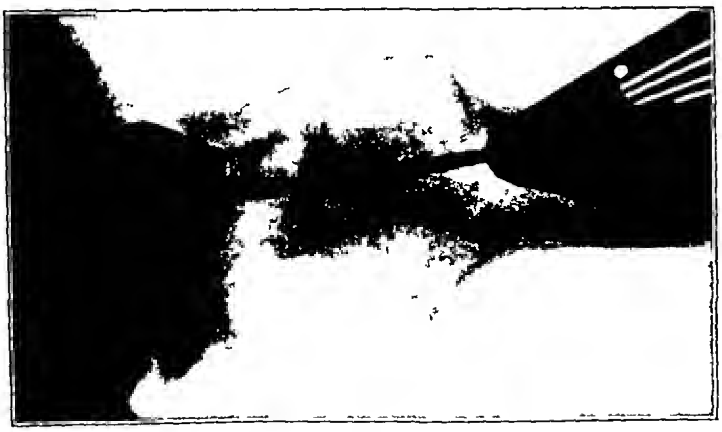

FIG 2

Case 43 Lateral roentgenogram showing how spikes of bone engaged and prevented reduction Non-union resulted Note the shadow of the director illustrated in Fig 1,*D*

In the intervals, while the roentgenograms are being developed, the graft is cut from the lower half of the fibula To prevent the fibula from splintering it is first weakened by several drill

holes at the line of section The muscular ridges on the graft are removed with a file until the whole graft can be just passed through one of three holes on a perspex gauge (Fig 1, I) These holes measure one-half inch, seven-sixteenths of an inch, and three-eighths of an inch, respectively The fibular graft is then sawed to the exact length of the trifin nail, which at this stage should be in place

A guide wire is passed along the hole in the nail, a long twist drill of the appropriate diameter (Fig 1,*B*) is taken on a brace, and a hole is bored above and parallel to the guide wire The required depth is marked on the drill, it is desirable to have the penetration of the graft one-quarter inch less than that of the nail The long shank on the drill is necessary in order to keep the handle of the brace from striking against the side of the thigh The drill is kept turning in the same clockwise direction when being withdrawn, in order to remove all the drillings The graft is then tapped into place, but one should make sure that it remains parallel to the guide wire as it goes in In ununited fractures the graft may catch on the sclerosed bone as it crosses the fracture line and may deviate from the channel drilled for it After final check roentgenograms, the wound is closed and the dressing is fixed with an elastoplast spica in order to make it secure against subsequent knee-flexion

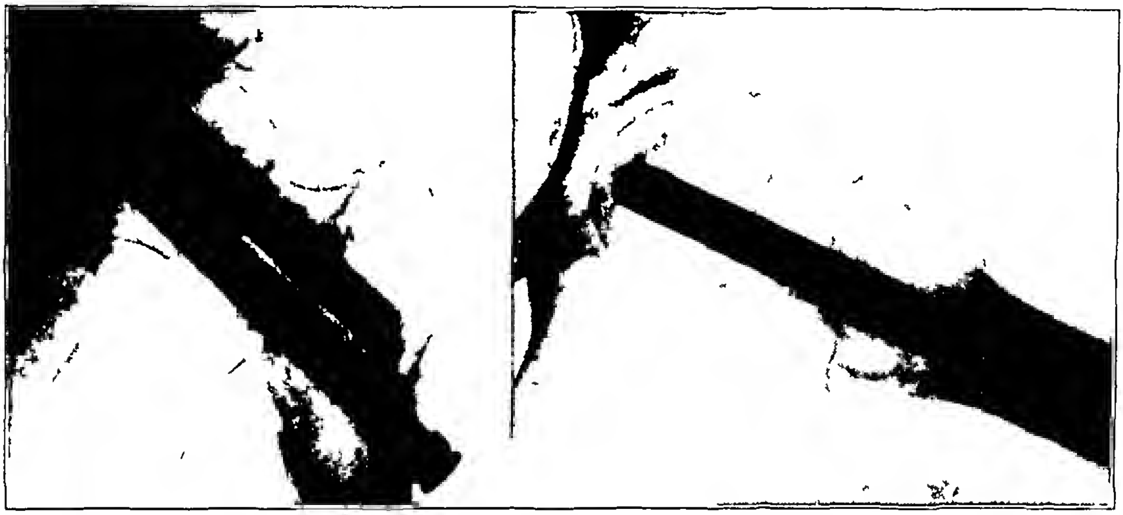

Fig 3-A Fig 3-B

Case 40 Roentgenograms show healthy appearance of bone, three months after operation

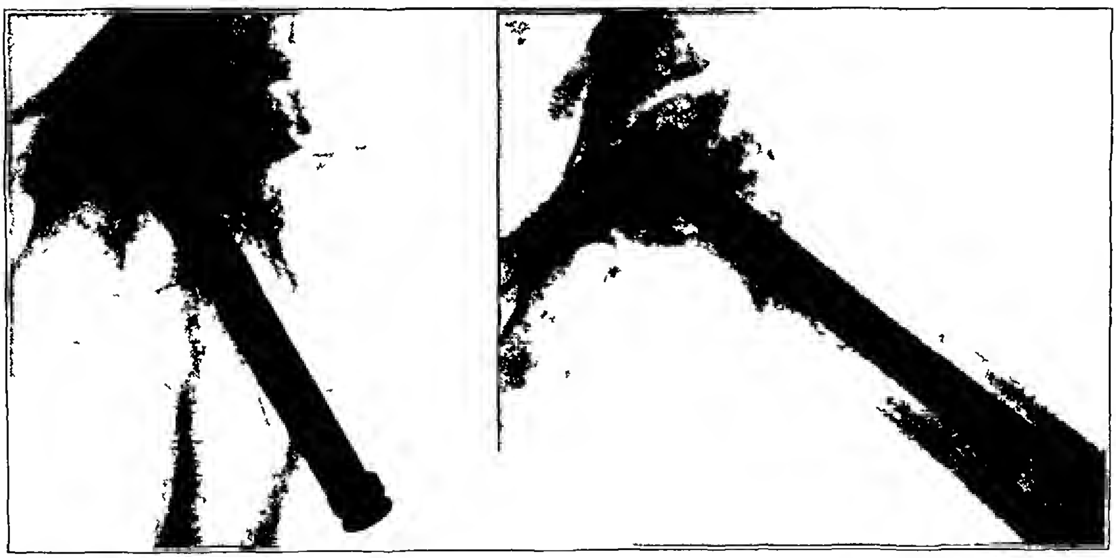

Fig 3-C Fig 3-D

Same case, three years after operation, showing typical aseptic necrosis

Fig 4-A

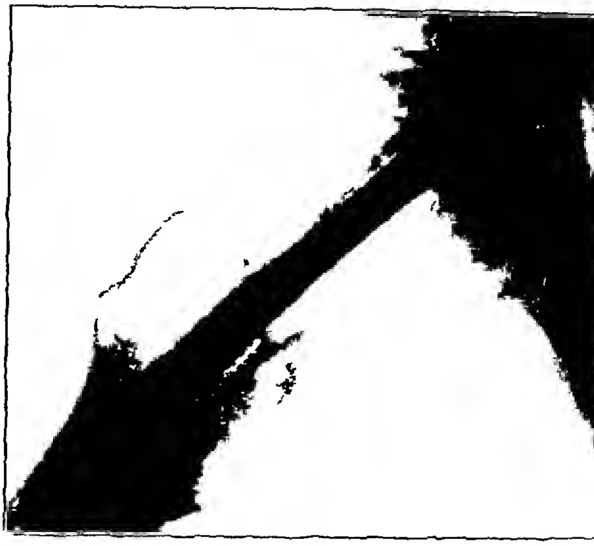

Fig 4-B

Figs 4-A and 4-B Case 41 Roentgenograms show healthy appearance of bone, three months after operation

Fig 4-C Same case three years after operation, showing aseptic necrosis This patient bore no weight on the limb for seventeen months after operation and has never borne his full weight on it

Fig 4-C

and hip-flexion exercises The addition of the graft extends the operation time by only a few minutes

Subsequent treatment follows the generally accepted principles of early joint movement and absence of weight-bearing on the injured extremity for three or four months The patient is usually allowed to get about on crutches from the fifth day onward Some oedema of the ankle is usual and is controlled by the wearing of an elastic stocking for six months

RESULTS

When a fibular graft is combined with a nail, bony union is generally established within six months Aseptic necrosis, however, may not appear until after the first year has elapsed, and evidence of osteo-arthritis from other causes may not be found until well after the first year It was considered, therefore, that a two-year follow-up should be accepted as the minimum period in assessing results

Of the 107 cases, sixty-three were done two years or more ago, five patients being operated on three months or more after the injury Death due to operation and to natural causes reduced the number of two-year follow-up cases to forty-seven, and it is on this small series that the results are based (Table I)

Mortality

The mortality of 8 per cent was accounted for mainly by operation being done on patients in poor condition, whose chances of survival without pinning were slight (Cases 58 to 62, Table II) Compared with other published figures, the addition of the graft does not appear to affect the mortality adversely

Fig 5-A Fig 5-B

Case 32 Roentgenograms taken soon after operation show graft just reaching joint line

Non-Union

Non-union occurred in 13 per cent (Cases 42 to 47) Two patients fell within three weeks of operation and broke the nail and graft out of the head In a third patient, infection developed in the wound after an attack of postoperative delirium in which she removed the dressing and several stitches In two cases the nail and graft were placed too far forward in the head, owing to difficulty in getting a satisfactory lateral roentgenogram during the operation, the nail and graft broke out of the head within ten days The fracture in the sixth case could not be properly reduced in spite of every manoeuvre (Fig 2), and union failed to occur

Thus all cases of non-union were accounted for by accident or by errors of technique Among the forty-one cases in which union did occur were five cases of previous non-union, although one patient (Case 48) died one year after operation

Fig 5-C

Same case, four years after operation, showing slight osteo-arthritic changes where graft touches joint

Aseptic Necrosis

Aseptic necrosis developed in four patients (Cases 38 to 41), in all of whom bony union had occurred As in other series reported, most of the cases were below the average age (fifty-eight, seventy, sixty-four, and thirty-nine years, respectively)

In two of the patients, necrosis developed within one year of operation and progressed to typical collapse of the head and osteo-arthritis (Figs 3-A to 3-D) The third patient had roentgenographic evidence of aseptic necrosis at fifteen months, but even four years after operation he complained of only mild osteo-arthritic symptoms and had only slight deformity of the head

TABLE I

RESULTS OF TREATMENT OF INTRACAPSULAR FRACTURES WITH A COMBINED NAIL AND FIBULAR GRAFT

Total number of cases		63
Died in hospital following operation	5 (7.9 per cent.)	
Died within two years from natural causes	10	
Untraced	1	
	16	
Number of two-year follow-up cases		47
Bony union	41 (87.2 per cent.)	
Non-union	6 (12.8 per cent.)	
Aseptic necrosis	4 (8.5 per cent.)	
Osteo-arthritis due to graft penetrating joint	10 (21.3 per cent.)	

The fourth case (Case 41) was of special interest. The patient was a tall man, aged thirty-nine, who had been thrown downstairs and had sustained an intracapsular fracture; this was fixed with a nail and a graft (Figs. 4-A and 4-B). At the end of four months

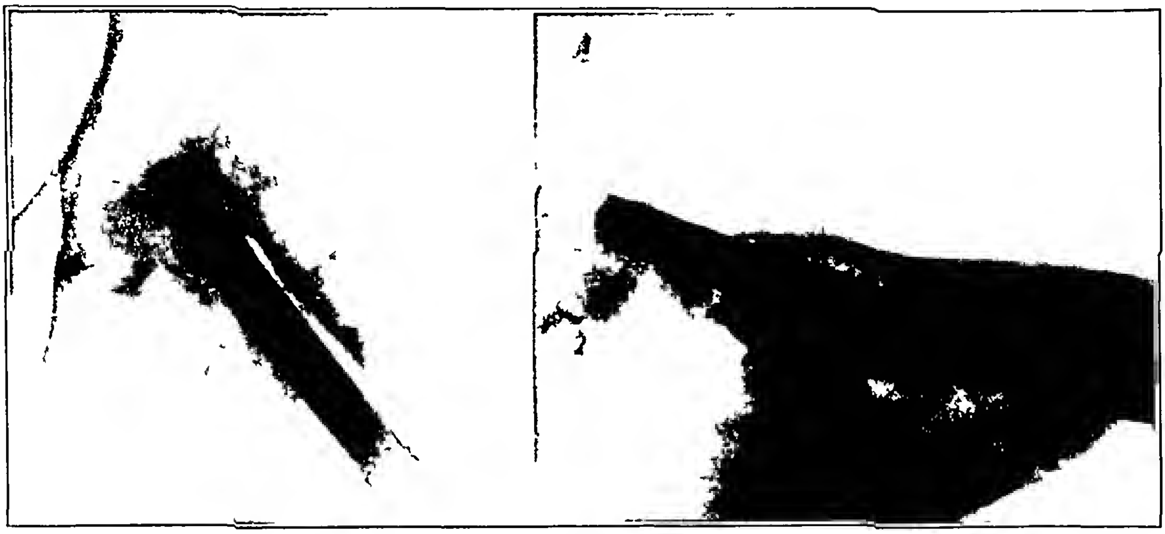

FIG. 6-A FIG. 6-B

Recent case (not in the series reviewed), showing position of nail and graft just after operation.

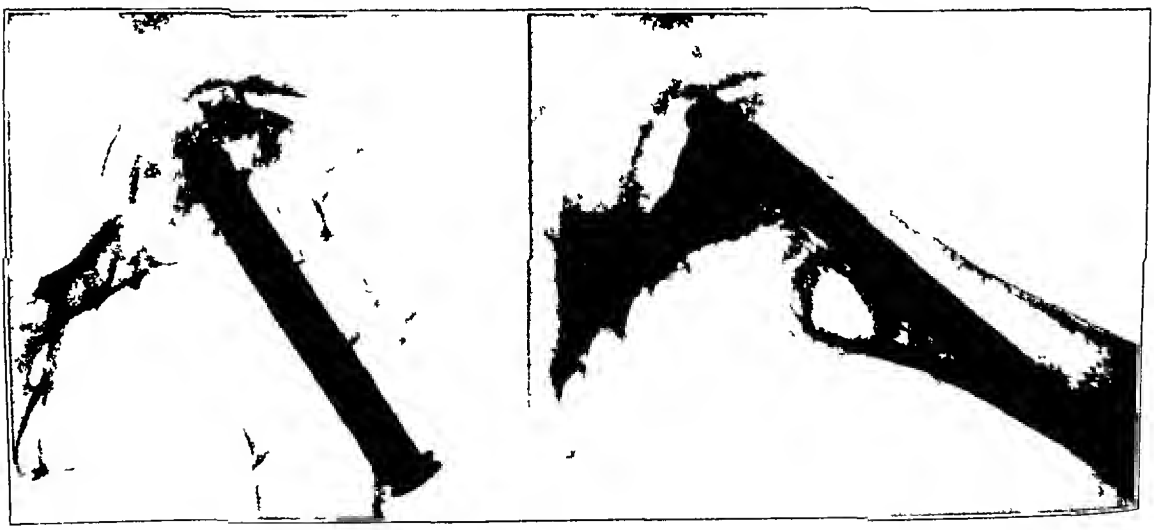

FIG. 6-C FIG. 6-D

Same case three months after operation. The patient had practised weight-bearing three weeks after operation, and impaction of the fracture occurred. The graft penetrated into the joint while the nail, on the other hand, was extruded.

TABLE II

DATA IN SIXTY-THREE CONSECUTIVE CASES OF INTRACAPSULAR FRACTURE TREATED WITH A TRIFIN NAIL AND FIBULAR GRAFT

Case No.	Age and Sex	Interval before Operation	Period of Non-Weight-Bearing (*Months*)	Follow-up Period (*Years*)	Range of Movement	Complications	Comments
1	62 F	4 days	3	6	Full		
2	55 F	35 days	3	6	Full		Graft placed below nail
3	73 M	3 days	3	5	20° limitation of flexion, rotation 30% of normal		Mass of callus formed around fracture
4	63 F	3 months	4	5	Full		
5	74 F	9 days	3	5	Full		Nail inserted ¼ inch too far at operation and withdrawn
6	55 F	35 days	3	5	Full		
7	61 F	6 days	3	5	Full		
8	73 F	1 day	3	5	Full		
9	64 F	3 days	3	4	Full		
10	65 M	16 days	3	4	Full		
11	42 F	7 days	8	4	Full		
12	56 F	13 days	3	4	Full		
13	72 M	3 days	3	4	Full		Had below-the-knee amputation in same extremity
14	67 F	3 days	3	4	Full		
15	70 F	4 days	3	4	Full		
16	54 F	2 days	3	4	Full		Seen in own home. Very nervous and refused to come for final x-ray. X-ray 2 years after operation showed union and no complications
17	73 F	4 days	3	3	Full		
18	74 F	1 day	4	3	Full		Died of cerebral thrombosis, 4 years after operation
19	52 F	4 days	3	3	Full		

(*Continued on page 74*)

TABLE II (*Continued*)

Case No	Age and Sex	Interval before Operation	Period of Non-Weight-Bearing (*Months*)	Follow-up Period (*Years*)	Range of Movement	Complications	Comments
20	67 M	6 months	3	3	Full		Treated initially as impacted fracture, but no union after 6 months
21	67 M	50 days	3	3	Full		
22	75 F	4 days	3	2½	Full		
23	87 F	5 days	3	2	Full		Died 26 months after operation
24	81 F	10 days	3	2	Full		
25	62 F	3 days	3	2	Full		Pin extruded at 6 months and was removed
26	71 F	4 days	3	2	Full		Died from pneumonia, 2½ years after operation
27	64 F	5 days	3	2	Full		Died from coronary thrombosis, 3 years after operation
28	38 M	8 months	4	6	20° limitation of flexion, rotation nil	Osteo-arthritis	Graft inserted to joint line Osteo-arthritis developed in fourth year No aseptic necrosis Still works as a miner
29	56 F	2 days	3	5	Full flexion, internal rotation limited	Osteo-arthritis	Slight localized osteo-arthritis developed in upper part of joint in fifth year, due to graft being inserted to joint line
30	59 M	8 days	3	4	30° limitation of flexion, rotation nil	Osteo-arthritis	Osteo-arthritis where graft reached joint line Slight limp, but working as laborer
31	70 M	5 days	3	4	90° of flexion, no internal rotation	Osteo-arthritis	Graft inserted up to joint Arthritis developed in this area Has to use a stick
32	58 F	45 days	3	4	Flexion full, rotation 30% of normal	Osteo-arthritis	Slight osteo-arthritis due to graft just reaching joint No limp Slight stiffness after sitting

(*Continued on page 75*)

TABLE II (*Continued*)

Case No	Age and Sex	Interval before Operation	Period of Non-Weight-Bearing (*Months*)	Follow-up Period (*Years*)	Range of Movement	Complications	Comments
33	55 F	4 months	3	3	Flexion full, slight limitation of internal rotation	? Osteo-arthritis	Doubtful area of osteo-arthritis where graft just reaches joint No symptoms
34	59 F	4 days	3	3	Flexion full, rotation 30% of normal	Osteo-arthritis	Graft just reaches joint No disability X-ray changes slight
35	73 F	3 days	½	2½	30° limitation of flexion, rotation 30% of normal	Osteo-arthritis	Graft just reached joint Local osteo-arthritis developed Graft broke but union occurred No limp
36	70 M	9 days	3	2½	Flexion full, rotation nil	Osteo-arthritis	Graft inserted to joint, causing osteo-arthritis Symptoms slight No limp
37	60 F	5 days	3	2	40° limitation of flexion, rotation 30% of normal	Osteo-arthritis	Graft inserted to joint line Symptoms of arthritis mild
38	58 F	9 weeks	5	4	Flexion to right angle, no rotation	Aseptic necrosis	Had Paget's disease of tibia and fibula of same limb Graft removed from other leg Necrosis first observed in eleventh month Collapse of head and osteo-arthritis followed
39	70 F	5 days	3	4	Full flexion, rotation 30% of normal	Aseptic necrosis	Slight limp, uses stick when outside Necrosis first noticed at 15 months No collapse of head
40	64 F	6 days	3	4	45° range of flexion, no rotation	Aseptic necrosis	Necrosis first observed at 7 months Collapse of head and osteo-arthritis followed
41	39 M	2 days	17	3	All movements extremely limited	Aseptic necrosis	Did not bear weight for 17 months Necrosis first observed about 21 months
42	76 F	7 days		5	90° range of flexion	Non-union	Fell and broke nail and graft out of head in third week

(*Continued on page 76*)

TABLE II (*Continued*)

Case No	Age and Sex	Interval before Operation	Period of Non-Weight-Bearing (*Months*)	Follow-up Period (*Years*)	Range of Movement	Complications	Comments
43	39 F	2 days	3	5	90° range of flexion	Non-union	Poor reduction, o ing to interlocki of fragments Su trochanteric ost otomy done
44	72 F	3 days		1	60° range of flexion	Non-union	Fell and broke n and graft out head in third wee Subtrochanter osteotomy done
45	67 F	3 days	9	3½	30° range of flexion	Non-union	Dressings torn off postoperative d lirium Fracture b came infected P extracted
46	69 F	6 days		2½	60° range of flexion	Non-union	Pin and graft place too far anterior in head and brok out Subtrochan teric osteotom done
47	74 F	14 days		2	30° range of flexion	Non-union	Pin and graft place too far anteriorl in head and brok out Patient nev left bed after op eration Died heart failure 2½ years later
48	60 F	1 year	3	9 months	20° limitation of flexion		Died one year late following operatio for pituitary ade noma Had no pai or limp in ex tremity
49	71 F	3 days	3		Full flexion, rotation 50% of normal		Died 15 weeks afte operation Oedema of both legs developed Heart failure
50	69 M	6 days	3	19 months	Full		Died 20 months after operation from cerebral thrombosis Had thrombosis in limb after operation
51	76 M	3 days	3	3 months	Full		Died 4 months after operation from a stroke

(*Continued on page 77*)

TABLE II (*Continued*)

Case No.	Age and Sex	Interval before Operation	Period of Non-Weight-Bearing (*Months*)	Follow-up Period (*Years*)	Range of Movement	Complications	Comments
52	70 F	3 days	3	4 months	Full		Mental symptoms developed, attempted suicide, admitted to mental hospital. Died at fifth month
53	69 M	3 days	3	7 months	Flexion full, rotation 50% of normal		Walked normally. Died from stroke, 10 months after operation
54	70 F	3 days	3	3 months	Full		Died 3½ months after operation from acute obstruction, due to carcinoma of colon
55	74 M	15 days	3	4 months	Flexion full, rotation 30% of normal		Died 5 months after operation from retention of urine and uraemia
56	70 F	6 days	3	11 months	Full		Died 15 months after operation. Cause of death not ascertained. No limp or pain
57	78 F	5 days	2	2 months	Full		Died at home, 3 months after operation, from pneumonia. Walked a little without help
58	84 M	10 days			Full flexion	Died	Died 7 weeks after operation, from pneumonia
59	73 M	5 days				Died	Died day following operation. Poor risk, had fever and slight delirium before operation. Operation delayed for 3 days
60	69 F	2 days				Died	Feeble, poor risk. Died 4 days after operation
61	65 M	19 days				Died	Had rales in chest before operation. Died day after operation
62	71 F	30 days				Died	Never left bed. Died from uraemia, 2 months after operation
63	83 F	5 days					Could not be traced after leaving hospital

of non-weight-bearing he had full joint movements and was free from pain. Owing to the development of a psychological factor, however, he could not be persuaded to put his foot to the ground, and he continued to walk with crutches and did not bear weight on the injured limb until seventeen months after the operation. In spite of this long period of freedom from weight-bearing, aseptic necrosis developed, clinically and roentgenographically, toward the end of the second year, and it eventually progressed to marked osteo-arthritis of the joint. At no time did he bear full weight on the limb and, therefore, very little collapse of the head occurred (Fig. 4-C).

Thus aseptic necrosis developed in only 9 per cent. of the cases as compared with 30 per cent. in a large series of 365 cases, reviewed by Per Linton, in which treatment was by a nail alone.

Osteo-Arthritis

Apart from cases of aseptic necrosis, osteo-arthritis occurred in 21 per cent. (Cases 28 to 37) and was due to the graft penetrating the joint. In these cases the graft was inserted rather close to the joint (Figs. 5-A, 5-B, and 5-C). It was not realized at the time that the usual roentgenograms in two planes might give only an approximate indication of the relation of the end of the nail and the graft to the joint, and subsequent roentgenograms showed that the graft had just penetrated the joint. In these cases, osteo-arthritic symptoms developed two or three years after operation, but in only two cases did the arthritis prove more than a minor disability. This penetration of the graft into the joint may also occur, if early weight-bearing and consequent further impaction take place (Figs. 6-A to 6-D). The living graft fuses more rapidly to the vascular basal fragment than to the head, and so tends to pass in toward the joint. The inert nail, remaining more firmly embedded in the relatively avascular head, tends usually to be extruded. To avoid penetration of the fibular graft into the joint, it should be inserted to a depth of about one-quarter inch less than the nail.

In no case was there any complaint of ankle weakness in spite of the fact that, in most, no regeneration of the fibula had occurred.

SUMMARY AND CONCLUSIONS

In the treatment of intracapsular fractures, the use of a fibular graft with a trifin nail does not increase the mortality, and the addition of the graft lengthens the operation time by only a few minutes.

In this small series of cases a much higher proportion of bony union occurred (87 per cent.) and fewer cases of aseptic necrosis appeared (9 per cent.) as compared with the published results of cases treated with a nail alone. The true figure for aseptic necrosis, however, can only be assessed after a clinical and roentgenographic follow-up of all the cases for a number of years, and the author's series of cases is too small to draw any hard-and-fast conclusions on this aspect of the condition.

In one patient, necrosis developed in spite of seventeen months of non-weight-bearing. It is evident that non-weight-bearing does not prevent necrosis, although, of course, it may minimize collapse of the head and be of some value in delaying the onset of osteo-arthritis. Early weight-bearing may result in further impaction and shortening of the neck and this may cause the graft to penetrate the joint. For this reason weight-bearing should be avoided for the first three months, and the fibular graft should be inserted a little less than the depth of the trifin nail.

The results in this small series of cases would seem to justify the use of a combined nail and fibular graft in all intracapsular fractures of the femur.

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DISCUSSION

MR H JACKSON BURROWS, LONDON, ENGLAND It is at once a privilege and an embarrassment to follow the giants In particular, it is hardly possible to speak of aseptic necrosis without using the name of Phemister Dr Phemister made known the concept of creeping substitution, and he has also demonstrated the fragility of the bone in the zone of replacement Dr Compere has reminded us how slowly cortical bone undergoes substitution This emphasizes the importance, when we are dealing with fractures of the long bones, of avoiding further damage, not only by proper handling of the injured limb, but also by avoiding unnecessary or unnecessarily extensive cutting operations when closed manipulation would suffice, or, conversely, fruitless closed manipulations when open operation would be less damaging

In aseptic necrosis of the femoral head a further complication arises,—namely, the proximity of a joint, and the evils of aseptic necrosis depend not merely upon the changes in the bone, but also upon the destruction of the articular cartilage For this we can do virtually nothing The ingenious operations which we have heard described will hasten repair of bone, but they can do little or nothing for the articular cartilage It is in prevention that we must seek salvation

Gentleness in reduction of congenital dislocation of the hip is universally accepted In slipping of the upper femoral epiphysis, the devastating sequel of forcible manipulation in some cases was first demonstrated by my late chief, Elmslie We are perhaps slow in learning the same lesson in fractures of the femoral neck Most, though not all, can be reduced by gradual weight traction, followed by very little subsequent manipulation,—mere medial rotation Delay is not hazardous if preoperative management is understood

DR ROBERT W JOHNSON, BALTIMORE, MARYLAND I want to congratulate the Program Committee on their arrangement of this Symposium, because they have given us a well-rounded picture of the whole problem Each of the essayists has added a definite contribution which is different from the others For that reason I would like to discuss briefly each one

Dr Compere I want to thank for the clinical confirmation and application of the experimental work which I presented as a thesis to this organization some twenty years ago I had begun to believe it had been forgotten There is, however, a note of hope that I would like to add to his statement that much of the bone in the region of a badly comminuted fracture is non-viable From subsequent studies in new bone and the formation of callus, I believe that the viability of bone cells in the comminuted fragments *in loco* is not of particular importance The ingrowing vessels coming to organize the blood clot bring with them embryonic fibroblasts, which are quite capable of assuming the whole job of new-bone formation The old bone acts as a suitable scaffolding for this work

Dr Phemister, as usual, has presented his surgical thesis, backed up by beautiful physiological and pathological data I could not, however, follow him quite to the end of his argument that the implantation of more dead bone—namely, the graft—in the head of the femur is actually going to prevent aseptic necrosis I believe that drilling of a rather large open tract will do more for vascularity than a graft, although it does not in any way take over the mechanical function of support of the region during the healing period It is simply a physiological rather than a mechanical argument

Mr Patrick has taken up the question where Dr Phemister left it, using a pin and graft in the acute fracture of the hip He has certainly shown encouraging and helpful results However, his follow-up is necessarily, in my opinion, too short to permit disposing of the problem of aseptic necrosis in the same manner as Dr Phemister has done, whose last case had a follow-up of seven and one-half years

These papers have given us a beautiful presentation of fracture of the neck of the femur and its problems, and what we should now know about them.

Dr J Albert Key, St Louis, Missouri I would like to mention a type of necrosis that I have seen many times In operating for osteomyelitis years after the acute disease, one may find layer after layer of dead bone which is completely surrounded by living bone That bone will stay there for many years before it is absorbed A similar necrosis may occur at the ends of the fracture fragments, and this may be one cause of non-union

Dr Dallas B Phemister (closing) Mr Burrows spoke of the necrotic articular cartilage It may persist for years in regions inaccessible to the invading blood vessels and connective tissue, but they may reach it along the surface or by growing through the underlying dead bone, and replace it by fibrocartilage Extending the drill holes through the cartilage hastens the invasion and replacement This should be beneficial, since Albert Key has shown experimentally that chipping off a fragment of articular cartilage and bone and leaving it in the joint favors the development of degenerative arthritis

As to the strong tibial bone grafts employed, I believe they are valuable in that they favor the union of the fracture, when present, and, placed in the upper portion of the dead head, they protect it against collapse, which is the worst of complications, while invasion and transformation into new bone are taking place

There is great difference of opinion as to when the bone dies in these cases of disturbance of its circulation by injury or occlusion I have studied microscopically between fifty and seventy-five femoral heads, removed either at operation or at necropsy, performed somewhere between a few days and fifteen or twenty years after the onset of the trouble The evidence has been that the bone always dies soon after the accident or onset of the disease which cuts off the circulation One must distinguish between the time when the bone dies and the time when this necrosis can be recognized clinically and roentgenographically Microscopic examination of specimens removed early shows that the bone dies soon after the circulation has been cut off Sections of older specimens show only the later changes However, months or, when the fracture has united, even one or two years may elapse before changes take place, such as atrophy of the adjacent living bone, creeping substitution, collapse, and arthritis, which make it possible to diagnose the condition clinically and roentgenographically It is a common error to assume that the bone dies at this late date and not at the onset of the trouble

Mr James Patrick (closing) I would like to comment on a case which throws some light on the viability of the head You will remember that I said one has to be careful not to put the graft too close to the articular surface of the head, for the usual roentgenograms taken in two planes do not always give a true picture of the proximity of the graft to the joint

Another factor sometimes appears There is a tendency for the graft subsequently to move in toward the joint A case was illustrated in which the patient did not follow her instructions about non-weight-bearing and did not report until four months after leaving the hospital During this period of early weight-bearing some collapse and impaction of the neck had occurred The pin, by reason of its physical pressure on the bone into which it had been driven, caused some reaction and absorption of the bone This occurred to a greater extent in the vascular basal fragment than in the head, and so the pin was extruded when the collapse of the neck occurred The graft, however, although perhaps regarded as dead tissue by some, is certainly not so dead as the nail Fusion of the graft to the relatively avascular head takes longer than fusion to the basal fragment, and so, when collapse of the neck occurred, the graft moved into the head and penetrated the joint I think this contrary shift of the nail and graft throws some light on the state of viability of the head, and indicates the need for caution in placing the graft

My figures of the incidence of aseptic necrosis, when a graft is used with the nail, confirm Dr Phemister's observations, and my preference for the fibula instead of the dense cortical bone of the tibia as a source of material for a graft is supported by Dr Compere's investigations

A METHOD OF SUBTROCHANTERIC LIMB SHORTENING *

BY LAWSON THORNTON, M.D., ATLANTA, GEORGIA

Since the introduction of treatment of trochanteric fractures by internal fixation, procedures have been developed and reported by a number of surgeons. Blount's method has been the most outstanding in trochanteric shortening, and White's in shortening the shaft of the femur.

The object of this presentation is to show a method, developed more recently, which provides, before the osteotomy is done, for preservation of the normal angle between the femoral shaft and the neck. The method differs from others only in detail and in the use of a different design of instrument for internal fixation. The normal anatomical relationship of the trochanter and the shaft is maintained by this procedure. No external fixation is applied.

By following the details as presented here, plus the use of the specially designed trochanteric plate and Smith-Petersen nail†, an accurate procedure may be carried out. In the author's experience over a number of years, this plate and nail have always remained intact and the connecting screw has always held.

The technique is essentially that used in treatment of trochanteric fractures. The upper third of the shaft of the femur and the trochanter are exposed by a lateral incision. First, the Smith-Petersen nail is driven at the proper angle to make the plate fit along the lateral surface of the shaft and to maintain the normal angle between the femoral shaft and neck. In order to accomplish this accurately, a guide is necessary (Fig. 1).

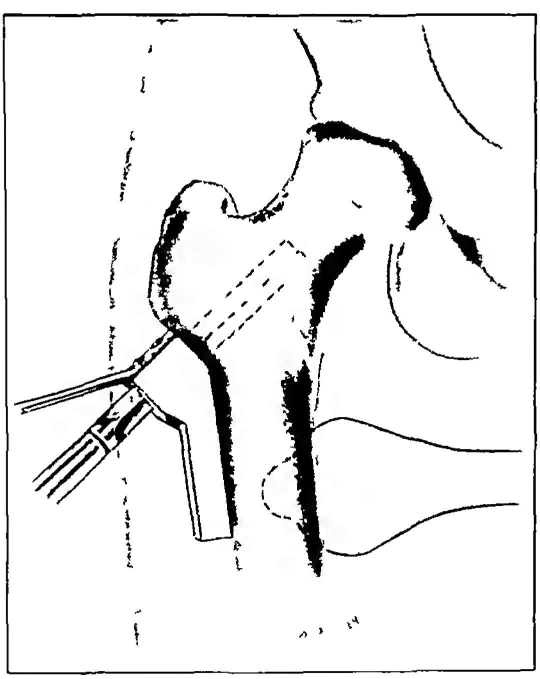

FIG. 1

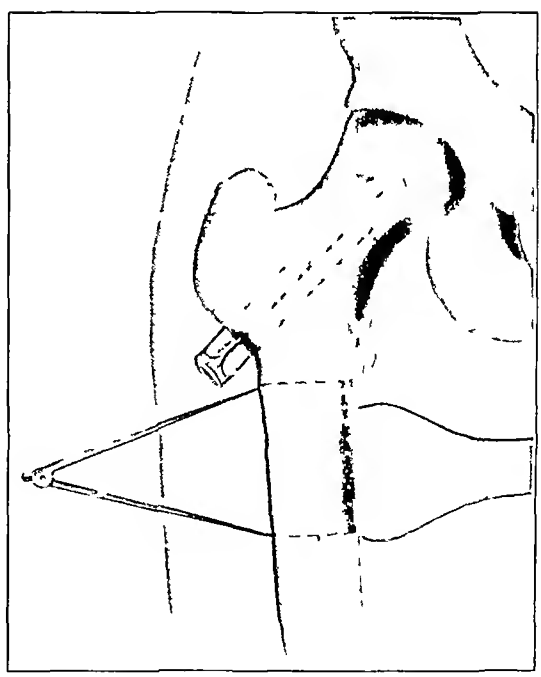

FIG. 2

Fig. 1. Guide for driving Smith-Petersen nail.

Fig. 2. Section of bone to be excised has been measured with calipers. Saw cut indicates where fragments are to be set.

* Read at the Joint Meeting of The American Orthopaedic Association, The British Orthopaedic Association, and The Canadian Orthopaedic Association, Quebec, Canada, June 3, 1948.

† Trochanteric plates of faulty design have been placed on the market, which may be expected to become disconnected or to break or bend.

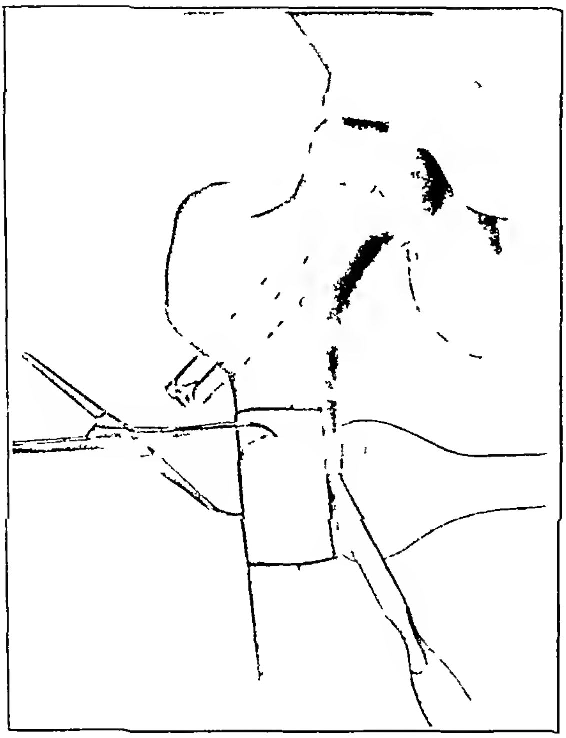

FIG 3

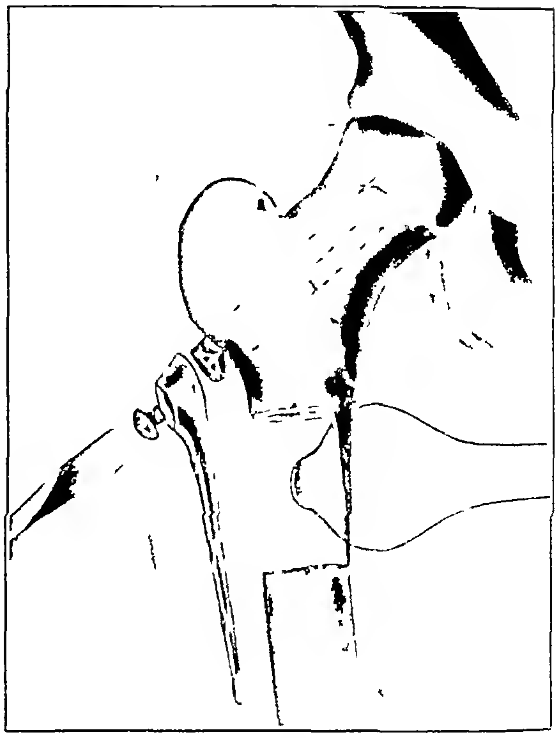

FIG 4

Fig 3 Shows method of cutting bone
Fig 4 Plate is about to be attached to nail Later, just before closure of incision, the connecting screw should be tightened forcibly with a large screw driver Note flange of bone which has been retained

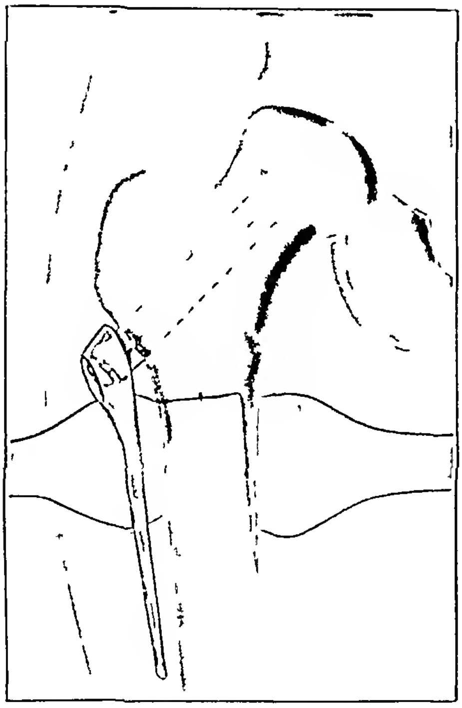

FIG 5
Fragments have been aligned

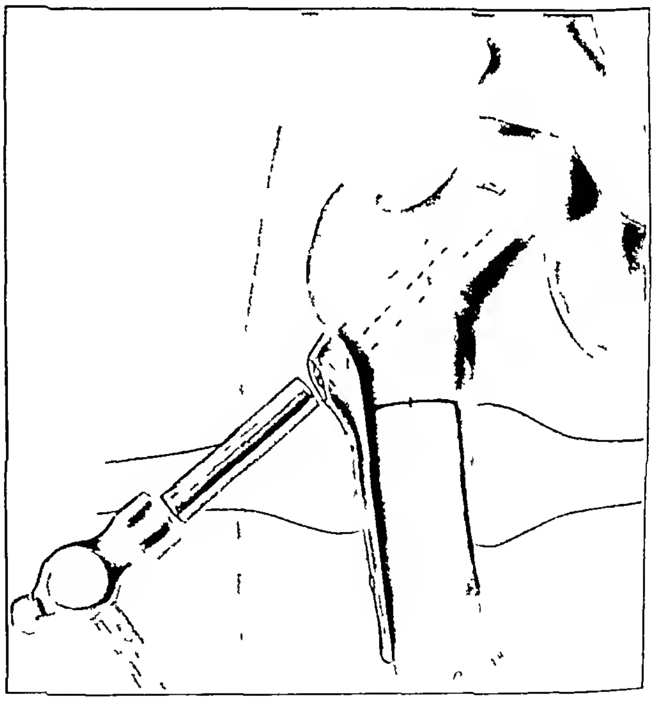

FIG 6
The nail has been driven in completely

About one-half inch of the nail is left protruding, so that later the plate and screw may be attached The use of several Barr-Bennett retractors gives adequate exposure of bone and prevents soft-tissue damage by saw and chisel *The section of bone to be* excised is measured with calipers A saw cut, along the cortex of the bone, constitutes a marker to be used in setting the fragments without abnormal rotation (Fig 2)

Either a broad, sharp chisel or a broad motor saw, or both, may be used for cutting

the bone (Fig 3) Since the trochanteric portion of the femur is broader than the shaft, the bone may be carved so as to leave a flange of bone extending down along the medial

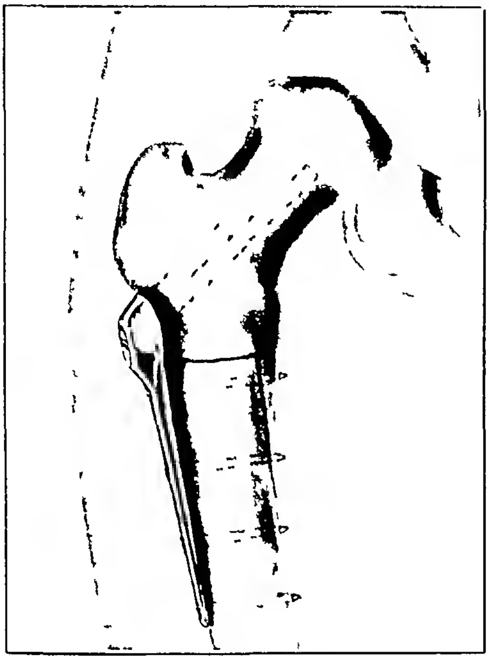

FIG 7

Fig 7 The plate has been fastened to the femoral shaft so that the screws engage both cortices

Fig 8 Case 1 After left subtrochanteric shortening

FIG 8

FIG 9

Case 2 Roentgenogram of left femur after shortening

FIG 10

Case 3 Two-inch shortening of right femur

cortex This flange makes the setting easier and is helpful in fixation and in obtaining bony union

Before the fragments are set, the plate is attached to the nail (Fig 4) The fragments, which have been freely exposed subperiosteally, are brought into apposition, and the saw cuts are matched (Fig 5)

Driving the nail is then completed (Fig 6) and the plate is fastened to the femoral shaft by screws which penetrate both cortices (Fig 7) The last and most important detail is that the connecting screw be tightened forcibly A large screw driver is used

Convalescence is the same as that following a trochanteric fracture No external fixation, suspension, or traction is used The usual postoperative nursing care is required, the leg being kept comfortable on a pillow and opiates being administered as needed during the first few days

When the period of discomfort has passed, the patient gradually increases independent activities and has freedom of the bed Reasonable care is advised until there is union at the site of the osteotomy Callus formation, as shown by roentgenogram, is helpful in determining the progress toward full weight-bearing Ten or twelve weeks in bed are recommended, followed by walking with crutches and gradually increasing weight-bearing Physical therapy is helpful for the muscles of the shortened extremity Training and development of the habit of walking in a natural way add much to the end result

Removal of the metal used for fixation is desirable at some future date

DISCUSSION

Considerable responsibility is associated with surgery for shortening the normal lower extremity, and this responsibility must be shared by the surgeon as well as by the patient and his family The surgeon's experience and results with internal fixation of trochanteric fractures may be the deciding factor

CASE REPORTS

CASE 1 E M , an eighteen-year-old girl, had one and one-half inches of shortening of her right femur as a result of old healed osteomyelitis of the upper portion of the femur, involving the upper femoral epiphysis, the head, and the acetabulum On March 5, 1945, she was referred by the author to Dr Smith-Petersen for arthroplasty An excellent result was obtained Because of the inequality in limb length of one and one-half inches, her gait was not in keeping with such a good hip

On June 26, a lift of one and one-half inches was put under her right foot and roentgenograms were taken (This amount of elevation was needed to square the pelvis and make the spine straight, but the shortening required would be one and three-eighths inches) On June 29, with pentothal anaesthesia, subtrochanteric shortening of one and three-eighths inches was done on the left lower extremity, at the Piedmont Hospital A Smith-Petersen nail and the plate illustrated were used (Fig 8)

After four weeks, the patient left the Hospital Roentgenograms, taken on September 5, showed evidence of union at the site of osteotomy, but not sufficient to permit her to be up By October 23, she was able to bear weight without crutches, and roentgenograms on December 4 showed solid union

On July 10, 1946, under general anaesthesia, the nail and plate were removed The patient remained in the Hospital for one week, and the sutures were removed after she went home, on July 22

When last seen, on January 29, 1948, this patient was walking well and was about to be married

CASE 2 C H was a seventeen-year-old girl, who had had pyogenic disease of the right hip when she was seven years old The femoral head had become necrotic and sequestrated The infection had cleared, leaving fibrous ankylosis with adduction-flexion deformity Later a hip fusion was done, followed by subtrochanteric osteotomy for correction of the adduction-flexion deformity

There was one and one-half inches of shortening by measurement, this shortening was also determined by placing enough blocks under the right foot to equalize the length In addition, a cork lift of one and one-half inches was added to the sole of the right shoe, and the patient found after several days' trial that this was the amount needed to equalize the length of her extremities

On March 19, 1947, at the Piedmont Hospital, the trochanter and upper femoral shaft on the left were exposed by the usual lateral approach A segment, one and one-quarter inches long, was removed, leaving a distally projecting tongue on the medial aspect of the proximal fragment The distal fragment was fitted into this notch against the proximal fragment and was fixed in place with a Smith-Petersen nail, plate, and

screws (Fig 9) A little space was noted anteriorly in the fitting of the fragment, but the joining was tight posteriorly and the anterior space was filled with cancellous bone The wound was closed as usual, and an elastic-bandage spica was applied A blood transfusion was given during the procedure and the patient returned to her room in satisfactory condition Penicillin was administered postoperatively and continued for five days

On April 21, roentgenograms showed excellent position and fixation with some early callus The postoperative course was satisfactory and the patient was discharged from the Hospital on May 7 Approximately three weeks later she began walking with the aid of crutches Roentgenograms on June 16 showed union at the site of the osteotomy By September 1 she was walking well and had no discomfort

In May 1948, the plate, nail, and screws were removed The incision healed by first intention

CASE 3 A M F, a girl, nineteen years old, had had pyogenic disease of the left hip, which healed with solid bony fusion plus adduction-flexion deformity She walked with a four-inch lift on her left shoe After subtrochanteric osteotomy for correction of 20 degrees of adduction and 20 degrees of flexion deformity, there remained two inches of difference in the length of the lower extremities

On March 14, 1947, at the Piedmont Hospital, a femoral shortening of two inches was carried out By a lateral incision, the trochanter and upper shaft of the right femur were exposed, and a two-inch segment was removed from just below the greater trochanter A medial tongue was left on the proximal fragment, and the fragments were accurately approximated Fixation was by a Smith-Petersen nail plus plate and screws, the proximal screw engaging the proximal and distal fragments The wound was closed in layers, and the usual dressing with an elastic-bandage spica was applied A blood transfusion was given during the operation The patient had no unfavorable reaction (Fig 10)

On March 31, the wound had healed *per primam* and the sutures were removed The patient was discharged from the Hospital, but was cautioned not to begin weight-bearing until roentgenograms had been taken, at the end of three months When seen on October 21, she was walking well with only slight lameness

SUMMARY

It is suggested that this plan for subtrochanteric shortening of the lower extremity may have the following advantages

1 Before the osteotomy is done, provision is made for maintaining the normal angle between the shaft and the trochanter

2 No external fixation is used

3 The trochanteric flange adds strength, stability, and bone contact, in addition to being helpful in the setting

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DISCUSSION

DR WALTER P BLOUNT, MILWAUKEE, WISCONSIN The paper which Dr Thornton has so beautifully and so modestly presented illustrates an excellent method of shortening the lower extremity There is no need for him to go into the indications, we all know them The question is "What is the best method of equalizing limb length after growth has stopped?"

To shorten a femur in the middle third is an operation of considerable magnitude It carries greater risk of deformity, such as bowing or angulation of the shaft, than an operation at the proximal end I noticed no complications in Dr Thornton's cases, and there is no reason why there should be any Operation in the middle third requires a cast in most instances There is sometimes delay in union, which is not so likely where the bone has been cut in the more vascular proximal portion There is no question about the distal third I think that no one would attempt the operation there

I have used a method very similar to the method just shown, which was suggested to me by Hugh Smith in 1943 I have tried it out in various conditions and used it for different degrees of shortening I have used a

blade-plate, a modification of Austin Moore's plate, instead of Dr Thornton's appliance Dr Farill, who is here, and I conceived this idea of internal fixation of an osteotomy independently In one case, with one and one-quarter inches of shortening, good progress was made because the boy was fifteen Five months later there was solid union After fourteen months of fixation the device was removed and the hip was nearly normal I do not know whether or not it is necessary to take out the fixation device In older patients and with inert metal, it is not necessary In the boy just described, I took it out

The danger in older patients is chiefly that of delayed union Dr Thornton left a tongue of bone on the proximal fragment I did that in one case, but it did not prevent delayed union I have done eight cases, with delayed union in one and non-union in one I urge the use of additional bone from the site or from the bone bank to ensure union

I mentioned only eight cases because in Wisconsin, at least, we do not often have to shorten the lower extremity We arrest growth in time by the excellent method of Dr Phemister or by stapling the epiphyses, and rarely do we have patients with very unequal limb length

It seems significant that this paper was presented immediately after the ones on avascular necrosis I should urge that care be taken not to produce too much trauma, because of the danger of this complication We all know that it may occur in intertrochanteric fractures It would be too bad to *produce* a fracture below the hip in a patient from eight to fifteen years of age and to obtain avascular necrosis

Another possibility is the use of the Kuntscher nail as internal fixation in the shortening operation Dr Carpenter and his co-workers recently demonstrated this beautifully I rather think that Dr Thornton's method and my method may be supplanted in the near future by the use of the Kuntscher nail

Dr J Warren White, Greenville, South Carolina I appreciate Dr Thornton's bringing this method to our attention It is an excellent way of doing shortening of the femur and I am using it in selected cases, but I still feel that shortening in the middle third is the method of choice This contribution, I think, has great value in those cases where you have to do more shortening than is possible in the middle third There is a certain amount of difficulty in closing the wound when more than two inches of shortening are done in the middle third This subtrochanteric shortening is of particular value in those patients having bulky thighs, for the closure is much easier, owing to the relative difference in the amount of soft tissue present

I wish that more people would consider shortening in the middle third I have done a great many such operations, without the mechanical difficulty that I have had with five or six subtrochanteric shortenings Of these subtrochanteric shortenings, I have had two with delayed union and one with non-union Of the shortenings in the middle third, I have had no delayed unions or non-unions

Dr J Albert Key, St Louis, Missouri I have used the subtrochanteric method and I do not like it very well I shorten the femur in an adult with a good deal of trepidation I cut the bone with a Gigli saw, which seems to me the easiest method I think it would be difficult for me to make this tongue as Dr Thornton has suggested One should be sure to get the blade or nail-plate in position before cutting the femur In one instance my Gigli saw cut a little too far and the femur broke before I got the blade or nail-plate into the neck of the femur I was faced with the troublesome problem of how to overcome the posterior displacement of the distal fragment Also, after you leave the lesser trochanter you are not dealing with cancellous bone It takes just as long for it to unite here as in the middle portion of the shaft Therefore, I am still in a quandary I think I prefer an oblique or Z-plastic method, with the osteotomy in the lower portion of the femur and internal fixation of the fragments

Dr Lawson Thornton (closing) Subtrochanteric femoral shortening, which was originated by Dr Blount, has become generally used The object of this presentation is to show another technique, in which the Smith-Petersen nail plus an especially designed trochanteric plate are employed

THE USE OF SKELETAL TRACTION IN THE TREATMENT OF FRACTURES OF THE FEMUR *

BY EDWARD M. WINANT, M.D., NEW YORK, N.Y.

During the first years of World War II, compound fractures of the femur resulting from battle injuries were treated, for the most part, by Orr dressings and immobilization in plaster-of-Paris spica splints. In 1944, concurrent with the advent of delayed primary closure of wounds, this treatment was discarded in favor of skeletal traction. It was felt that this change in treatment would result in a better position of the major fracture fragments, maintenance of limb length, and improved knee and ankle motion.

In this study of sixty-eight fractures of the femur which were treated by skeletal traction in an Army General Hospital, traction was accomplished by the use of the Kirschner wire and the extremity was supported in balanced suspension. The Pearson attachment was used in conjunction with the Thomas splint, in order to establish early knee action. Supracondylar traction was preferred to that obtained through the tibial crest. The supracondylar region was selected for the insertion of the Kirschner wire, unless contra-indicated by the presence of a soft-tissue wound involving this region of the thigh or by a fracture of the distal three inches of the femur.

TABLE I

TYPES OF FRACTURES TREATED

	Simple	Compound	Total
Comminuted	1	38	39
Oblique	4	18	22
Transverse	2	5	7
Totals	7	61	68

Supracondylar Traction

Since a difference of opinion exists regarding the choice of site for insertion of the Kirschner wire, the advantages obtained from supracondylar traction will be stressed. The general rule governing the use of skeletal traction—that is, never cross a joint unless necessary—still holds in this instance. If we are seeking skeletal traction, why depend upon the transmission of this traction through the soft tissues of a joint? A protective mechanism is gained from the soft tissues interposed between the skin and femur, which act as a barrier against infection extending from skin to bone. In addition, these soft tissues serve as a cushion, lessening the possibility of skin necrosis from pressure of the wire spreaders. Should pressure necrosis occur with tibial traction, the bone is exposed, thus predisposing to the development of osteomyelitis. Furthermore, if supracondylar traction is utilized in conjunction with knee motion, the mechanical advantages can readily be appreciated. There is no local irritation of the femur resulting from flexion and extension of the tibia, and traction is maintained through the same plane. With tibial traction, on the other hand, the tibia rotates around the Kirschner wire as the knee moves, and the possibility of pressure necrosis is enhanced. The Kirschner wire should be inserted under absolute

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 28, 1948.

Fig 1-A

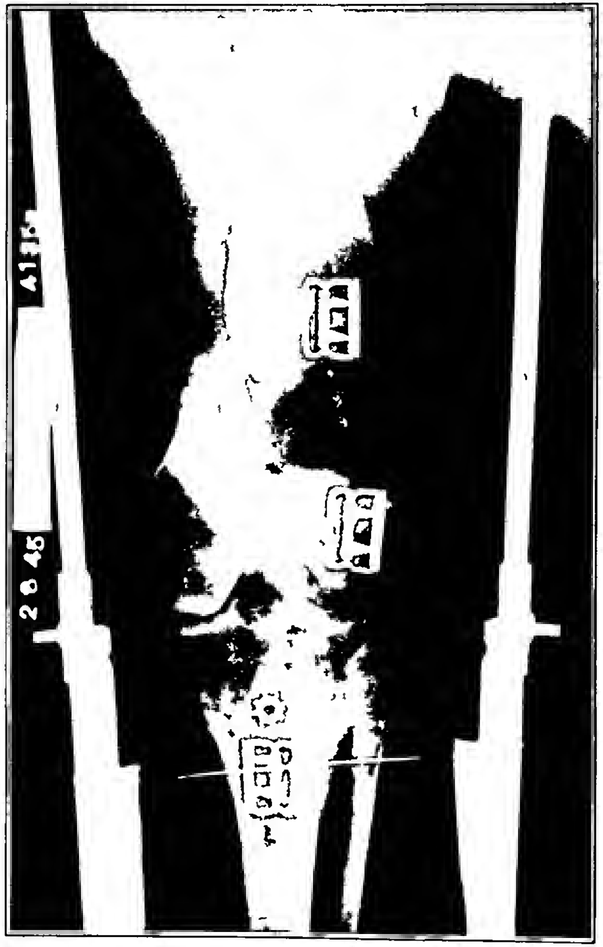

Fig 1-B

Fig 1-C

Fig 1-A Shows considerable loss of bone substance and of limb length Soft-tissue destruction is present

Fig 1-B Limb length was gained by skeletal traction, and the position was held until soft-tissue healing permitted internal fixation with metal plate and screws for further stability

Fig 1-C Anteroposterior and lateral roentgenograms, taken five months after bone-grafting with iliac bone and tibial onlay graft to replace lost bone, show solid bony union

TABLE II

RANGE OF KNEE MOTION

Degree of Motion	Number of Cases
Extension	
Full	61
Satisfactory (175 degrees or more)	7
Flexion	
Full	0
Satisfactory (90 degrees or more)	32
Unsatisfactory (less than 90 degrees)	36

aseptic technique, while the patient is in the operating room. Another measure for the prevention of infection and skin necrosis is the use of at least twelve dressings, four by four inches in size, placed over the end of the Kirschner wire. The innermost dressing should be sealed to the skin by collodion, and the remaining dressings should be held in place by a bandage before the wire spreader is applied. As a result of adherence to these principles, not a single case of infection or pressure necrosis of bone occurred at the wire site.

Skeletal traction was maintained until union of the fracture was solid clinically and roentgenographically, and weight-bearing with brace and crutches was possible. However, the traction was interrupted in practically every case during the course of treatment, since the majority of these patients had their initial treatment overseas and were placed in plaster spicas for the return trip to this country. The average length of time from injury to weight-bearing was 6.1 months.

Types of Fractures

A simple classification of the types of fractures treated (Table I) indicates that sixty-one of the total of sixty-eight were compound fractures. Thirty-nine of the total number were comminuted, seventeen had loss of bone substance. It was impossible to determine whether this loss of bone substance resulted from the original injury or, as suspected in many instances, from too ambitious débridement.

Knee Motion

One of the chief aims of treatment by skeletal traction, plus balanced suspension with the Pearson attachment, was to maintain a good range of knee motion. The range of motion obtained in these cases was disappointing.

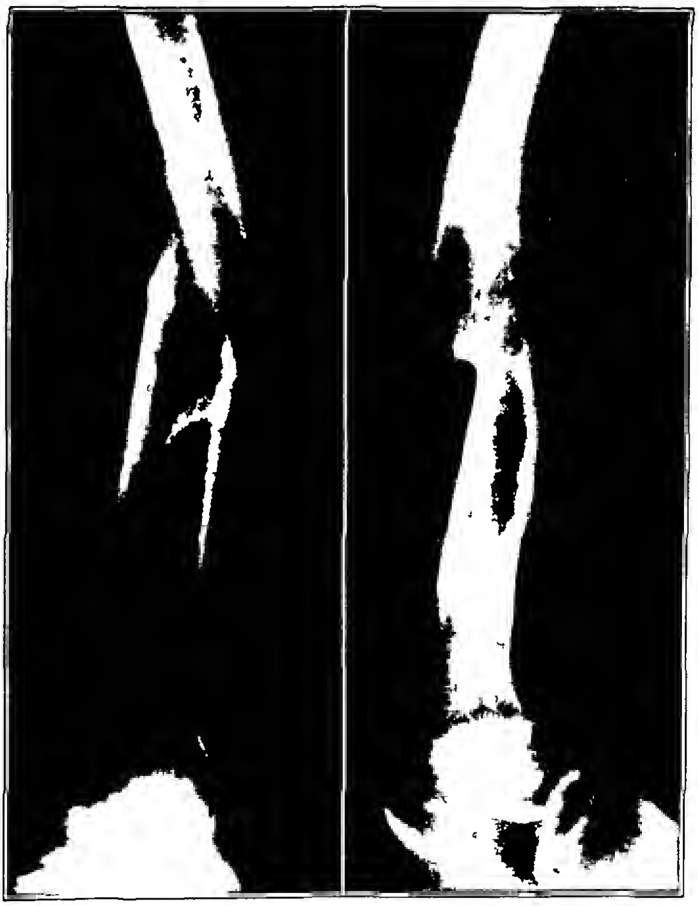

FIG. 2-A FIG. 2-B

Anteroposterior and lateral roentgenograms illustrating a case in which anatomical alignment of the fracture fragments was not obtained. However, good bone contact was present, and the functional position was considered satisfactory.

The apparatus does not permit full extension, and flexion is possible only to 135 degrees However, in some knees that could not approach even this limited range of motion, some knee function was maintained, this prevented a fibrous ankylosis which might have developed, had the extremity been immobilized in a circular plaster splint (Figs 1-A, 1-B, and 1-C) Because it was impossible to obtain a ring lock-knee brace, it was necessary to use a stiff toe-to-groin brace with an ischial ring, which held the knee in full fixed extension These patients were instructed to remove their braces and to exercise their knees, but, since the majority were granted convalescent furloughs, it is doubtful if the instructions were carried out conscientiously Consequently, motion was actually lost during this important period of treatment, whereas it would have been gained, had a knee-lock brace been applied to permit motion during non-weight-bearing These patients were followed for an average of only two and one-half months after weight-bearing had been begun, and the majority were given medical discharges while they were still wearing their braces The range of knee motion at the time of discharge is shown in Table II

Limb Length

Full limb length is not always maintained by skeletal traction With extensively

Fig 3-A Fig 3-B Fig 3-C

Fig 3-A Anteroposterior roentgenogram shows malposition and malunion of the fracture fragments, with overriding and poor bone contact

Figs 3-B and 3-C Anteroposterior and lateral views after open reduction and internal fixation with metal plate and screws and onlay tibial bone graft

comminuted fractures, impaction or shortening from overriding of the major fragments may result in better bone contact than would be obtained in an effort to secure full limb length While every attempt should be made to maintain limb length, shortening of as much as one inch will not prove to be a serious handicap to the patient The endeavor to maintain limb length should be tempered with caution, to prevent distraction of the fracture fragments

The final limb lengths in this series (Table III) indicate that 66 per cent of the cases treated by skeletal traction had up to one-half inch of shortening, extensive shortening of two inches or more was present in only two cases

Fig 4-A

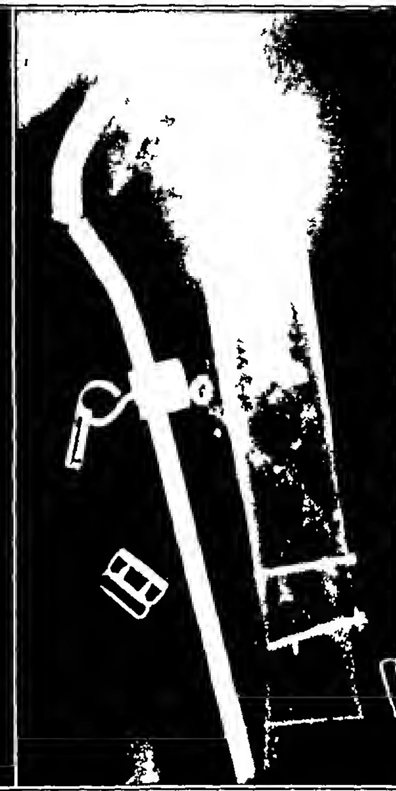

Fig 4-B

Fig 4-A Extensive comminution with loss of bone substance

Fig 4-B Limb length was maintained by skeletal traction until soft-tissue wounds had healed, permitting internal fixation and replacement of bone by dual tibial onlay grafts with metal screws Iliac ribbons of bone were placed in defect

Anatomical alignment of fracture fragments should not be expected with skeletal traction, however, a satisfactory functional position can be obtained (Figs 2-A and 2-B) In this series of cases, there was only one instance in which surgical intervention was necessary to correct malunion (Figs 3-A, 3-B, and 3-C)

Delayed Primary Closure

Thirty-eight delayed primary closures were performed on the sixty-one compound fractures In most instances this meant a débridement with closure of two wounds,—a wound of entrance and a wound of exit In other cases, when the injury was caused by shell fragments, closure of as many as six wounds was necessary No closure was considered successful until all wounds had healed Twenty-two, or 58 per cent, of the thirty-eight delayed primary closures were successful In the remaining cases with draining wounds, healing was by secondary intention, with no gauze or other foreign body inserted into the wound These patients received penicillin parenterally, and their wounds were dressed only at very long intervals In no instance was frank suppurative osteomyelitis encountered

Open Reduction with Internal Fixation

Open reduction and internal fixation, in conjunction with skeletal traction, were considered necessary in eighteen of the sixty-eight cases The reasons for the reparative surgery in these cases are as follows

Delayed union	8
Loss of bone substance	6
Refracture	3
Malunion	1

TABLE III

FINAL LIMB LENGTH

Limb Length	Number of Cases
Full length to ½ inch of shortening	45
½ inch to 1 inch of shortening	12
1 to 2 inches of shortening	10
2½ inches of shortening	1
Total	68

TABLE IV

TYPES OF INTERNAL FIXATION

Tibial onlay graft with metal screws	4
Tibial onlay graft with metal plate and screws	3
Tibial onlay graft with screws and iliac bone	2
Iliac bone with metal plate and screws	9
Total	18

Where loss of bone substance was encountered, bone-grafting was carried out only when marked shortening would result or when sufficient bone contact was lacking to ensure union. Although seventeen patients suffered some loss of bone substance, open reduction and bone-grafting (Fig. 4-A and 4-B) were considered necessary in only six instances.

In the eight patients operated upon for delayed union, an average of three and one-half months had elapsed since the injury. This may be considered a little early to form an accurate opinion. The decision to operate was based upon clinical evidence of motion at the fracture site and lack of callus formation at roentgenographic examination.

The three refractures occurred at the end of five, five and one-half, and six months respectively, which undoubtedly was too early to have solid bony union. One of these patients had a contributing injury when he was thrown to the floor of a bus while on his first pass from the hospital.

The one case of malunion occurred in a patient who, in addition to a transverse fracture, had sciatic-nerve paralysis, suffered from a causalgia requiring lumbar sympathectomy, and had repeated attacks of renal colic. Because of his complications, it was impossible to maintain proper immobilization in either skeletal traction or a plaster spica.

TABLE V

COMPLICATIONS

Complication	Number of Cases
Nephrolithiasis	3
Refracture of femur	3
Peroneal paralysis	1
Psychoneurosis	1
Fracture of tibial onlay graft	1
Bending of Lane plate with bowing at fracture site	1
Soft-tissue abscess (due to gauze dressing left in wound)	1
Refracture of wired patella	1
Frozen knee joint	1
Total	13

The types of internal fixation are shown in Table IV. Following open reduction and internal fixation, skeletal traction was resumed, to maintain position until bony union had occurred.

Complications

The complications encountered in this series of sixty-eight cases are considered minimal (Table V). All of the patients were comparatively young adults, in good general health at the time their injuries were sustained. Three patients had nephrolithiasis. One of these, as mentioned previously, also had causalgia. This patient had fractured his tibial onlay graft while still in traction.

The patient with psychoneurosis was able to complete the treatment of his fracture on the orthopaedic ward.

Another patient returned from a week-end leave, complaining of pain at the fracture site with weight-bearing. Roentgenograms showed that the metal plate was bent and that there was bowing of the femur at the fracture site. When he was questioned, the patient admitted that he had walked without the aid of brace or crutches. This occurred six months after internal fixation of the fracture.

The third refracture occurred in the patient who sustained an additional injury in a fall in a bus.

In one patient, who had had an uneventful convalescence with union of his fractured femur, a very definite soft-tissue abscess developed when he became ambulatory. The patient had little complaint of pain, and there was no evidence of bone destruction by roentgenogram. At the time of incision and drainage of the abscess, a four by four gauze was removed, which had been left in his wound at the time of débridement or delayed primary closure.

Due to refracture, it was necessary to do a partial patellectomy on a patient who had had a wiring of a fractured patella overseas.

Another patient required a "quadriceps-plasty" for a frozen knee joint. This improved his flexion from a fixed position at 180 degrees to flexion at 135 degrees.

SUMMARY AND CONCLUSIONS

Skeletal traction is an efficient method of treating compound, extensively comminuted, oblique fractures of the femur.

In the presence of extensive wounds of soft tissue and bone, skeletal traction is definitely the treatment of choice.

Supracondylar traction is preferred to traction through the tibial crest, because there is less chance of infection or of pressure necrosis of soft parts or bone. Traction through the involved bone is more efficient than traction through the tibial crest.

OPEN REDUCTION AND INTERNAL FIXATION OF FRACTURES OF THE LONG BONES*

BY HARRISON L McLAUGHLIN, M D , SAWNIE R GASTON, M D ,
CHARLES S NEER, M D , AND FREDERICK S CRAIG, M D , NEW YORK, N Y

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This paper presents a report of cases treated on the Fracture Service of the Presbyterian Hospital in New York, under the direction of William Darrach and Clay Ray Murray, during the last twenty years It deals specifically with the results in 200 consecutive shaft fractures of the weight-bearing bones, treated by open reduction and internal fixation

No follow-up was considered adequate until the patient had been examined at appropriate intervals for a period of at least a year Patients with fractured femora were followed for an average of 5 4 years, and those with fractured tibiae for 4 1 years There were six deaths Four were the result of concomitant injuries and occurred within the first few days One resulted from kidney disease, eight weeks following fracture, and one patient died in the electric chair, seven weeks after injury Fifteen cases had inadequate follow-up studies The progress of the fracture was uncomplicated in these cases, when the patients were last seen The remaining 179 cases, with adequate follow-up, form the basis of this report

Evaluation of the results from open reduction and internal fixation leads to erroneous conclusions, unless the material analyzed is first classified according to the groups in which the method was used In this study, the cases were separated into three groups (Table I)

TABLE I

Open Reduction and Internal Fixation in 200 Consecutive Shaft Fractures

	Tibia	Femur
By choice	53	12
By necessity	10	47
Compound fractures	74	4
Totals	137	63

1 *Operation by Choice* This group includes all cases in which the same eventual result might have been anticipated by the use of other methods of treatment

2 *Operation by Necessity* This group includes the cases not considered amenable to treatment by other methods, or those in which operative fixation was expected to produce results definitely better than could be obtained by other methods

3 *Compound Fractures* The various effects of an open wound upon fracture treatment warrant separate consideration of this group of cases

The numerous common variants influencing success or failure of fracture treatment will not be discussed in detail in this report An analysis of the role of such factors as the proper choice, timing, technique, and philosophy of operative fixation, the continuity and

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 28, 1948

TABLE II

OPEN REDUCTION AND INTERNAL FIXATION IN 179 CONSECUTIVE SHAFT FRACTURES OF THE TIBIA AND FEMUR

	Immobilization after Operation (*Per cent*)	Physiological Function Maintained (*Per cent*)	Protected Early Weight-Bearing* (*Per cent*)
By choice	9 8	86 9	81 9
By necessity	16 6	83 3	75 9
Compound fractures	56 0	43 9	42 1

* The average period of protected weight-bearing in all fractured tibiae in which internal fixation was done by choice was 1 3 weeks

rationale of after-care, and the cooperation of the patient will be reported elsewhere These factors have proved highly important in determining the quality of the individual results Faulty judgment in the choice of patient or fracture usually predicated an unsatisfactory result Except for defective technique, the most important single therapeutic factor in the production of poor results was operation done late or after other methods of treatment had proved ineffective The ease of reduction, the efficiency of fixation, and the prognosis varied directly in proportion to the speed with which the operation was carried out

Internal fixation in only one plane was found to be inadequate, unless supplemented by external immobilization Internal fixation in at least two planes proved to be essential for secure stabilization of all shaft fractures In the cases in which this was accomplished (Table II), maintenance of joint motion and muscle action throughout healing, as well as protected early weight-bearing, was found to be both possible and safe

Postoperative management depended upon certain features of the case in question External immobilization by plaster splints or encasements was used in the presence of the following conditions

1 Unreliability or disorientation of the patient

2 Fractures of the femur (spica) or tibia (toe-to-groin plaster) in children In no child was internal fixation done by choice

3 Decalcified or diseased bone, having poor holding power for screws

4 Imperfect fixation due to comminution or loss of bone

5 Imperfect fixation due to faulty operative technique

6 Infection (local rest of the part by splints until the infection was under control)

7 Severe soft-part damage (local rest by splints until soft-part reaction had subsided)

All externally immobilized extremities except when in a plaster spica (as in fractured femora in children) were also placed in balanced suspension for elevation, ease of nursing care, and maintenance of motion in the joints not immobilized In the absence of the indications just listed, the extremity was placed in balanced suspension which allowed motion in all joints In fractures of the femur, the limb remained in suspension until sufficient healing had taken place to make protected ambulation safe In fractures of the tibia, suspension was removed and protected ambulation was commenced as soon as the operative wound had healed and the associated soft-part reaction had subsided Many patients with fracture of the tibia were given a molded splint to wear while sleeping, after the suspension had been discontinued

Protection for ambulation was provided in the case of tibial fractures by a removable leg brace fitted with an ankle hinge, and in femoral fractures by a toe-to-groin caliper brace fitted with a knee-joint lock Occasionally a plaster-of-Paris walking boot was substituted for the leg brace in fracture of the tibia This non-removable, immobilizing form

TABLE III

Open Reduction and Internal Fixation in 128 Shaft Fractures of the Tibia and Femur*

	Non-Union	Loss of Fixation
Femur	0	1
Tibia		
Compound	6	0
Simple	1	0

* In each of the 128 cases, motion was maintained, early protected weight-bearing was carried out in 118

of protection was found to be inferior to a brace, and was used only when justified by some factor of time or expense.

The external immobilization necessitated by inadequate internal fixation usually was found to offset the main benefits of the internal fixation. Table III gives ample proof that the absence of external immobilization did not jeopardize the security of adequate internal fixation. The single loss of fixation occurred two months after operation in a patient who refused to wear his brace. The record fails to show any specific reason for the one non-union in a simple fracture of the shaft of the tibia. The cases of non-union following compound fractures of the tibia were all accounted for by the circumstances of the local lesions.

An adequate technique of fixation has proved of tremendous importance. By comparison, the fixation materials used have proved unimportant. Although various metals have been used with success, stainless steel has been found most dependable for general use. Vanadium has been discarded as unsatisfactory. Many Vitallium plates have been fastened to bone with stainless-steel screws without any discernible untoward effect.

Electrolytic reactions have been observed commonly at operations for the removal of stainless-steel fixation. The amount of reaction has varied directly with the duration of the exposure, and has been unrelated to the amount of metal exposed to the action of the tissue fluids. Frequently the reaction has been centered around the tightest of the screws to be removed, while adjacent looser screws were uninvolved. Despite laboratory postulates to the contrary, neither loosening, loss of fixation, nor interference with union due to electrolysis has been observed.

In addition to compound fractures in which the material producing internal fixation was inserted as a temporary splint designed to be removed after bone healing, late removal of fixation material for relief of local pain or tenderness was required in twenty cases. Evidence of some electrolytic reaction was observed in most of these cases, and could reasonably be considered as contributing to the production of local symptoms. To date,

TABLE IV

Bone Healing in 179 Consecutive Shaft Fractures of the Tibia and Femur

	Tibia			Femur		
	No. of Cases	Union	Non-Union	No. of Cases	Union	Non-Union
By choice	51	50	1*	10	10	
By necessity	10	10		44	43	1*
Compound fractures	60	54	6**	4	4	

* Successful union after bone-grafting.

** Three patients had successful union after bone-grafting, two had late elective amputation, and the remaining patient was transferred to another hospital and was not seen again.

TABLE V

ANATOMICAL RESULTS IN 179 CONSECUTIVE SHAFT FRACTURES OF THE TIBIA AND FEMUR

	No of Cases	Length		Axis	
		Normal	Short*	Normal	Visible Angulation**
By choice	61	58	3	61	0
By necessity	54	47	7	50	4
Compound fractures	64	59	5	63	1

* The greatest amount of shortening was 3 centimeters

** In twenty-seven cases slight angulation was visible by x-ray, undiscernible by clinical examination

this complication has not been encountered during the period of usefulness of the plate or screws In fourteen additional cases, removal of the fixation material was required for other reasons

"Electrolytic osteitis" has not been encountered as a clinical entity Areas of bone absorption adjacent to plates and screws have been observed to be the seat of electrolytic reaction Most areas of absorption, with or without electrolytic changes, were traceable to infection or defective technique of fixation Although an undesirable phenomenon, electrolysis has proved to be of minor clinical significance as long as the fixation material was reasonably inert and had been properly applied

RESULTS

Of 200 fractures through the shaft of the tibia or femur treated by open reduction and internal fixation since 1928, 179 are sufficiently documented to be included in an end-result report

Bone Healing

At operation, a major portion of the tissue debris and hemorrhage usually was evacuated, so that in cases with adequate fixation there was minimal formation of external callus In the presence of non-rigid fixation, the amount of callus usually was increased Bony union in rigidly fixed fractures occurred by gradual disappearance of the fracture line, consequently an estimate of the time of bony union was impossible Clinical evidence of union in these cases was present from the start The incidence of bony union and of non-union is recorded in Table IV

Wound Healing

Fifty-nine simple fractures of the femoral shaft were operated upon There were no

TABLE VI

ADJACENT JOINT MOTION IN
179 CONSECUTIVE SHAFT FRACTURES OF THE TIBIA AND FEMUR*

	Tibia			Femur		
	No of Cases	Normal	Limited	No of Cases	Normal	Limited
By choice	51	50	1	10	6	4
By necessity	10	8	2	44	32	12
Compound fractures	60	51	9	4	3	1

* All motion defects of more than a few degrees resulted from some special complication or from external immobilization

TABLE VII

SYMPTOMS ENCOUNTERED IN
179 CONSECUTIVE SHAFT FRACTURES OF THE TIBIA AND FEMUR

End Result	Tibia	Femur
Asymptomatic	87	44
Bad-weather pain	12	6
Other pain	5	1
Pain requiring late removal of fixation material	17*	7*

* Pain was relieved after removal of fixation material in all cases.

TABLE VIII

AVERAGE TIME OF ECONOMIC RECOVERY

	No. of Cases	Patients Capable of Former Work	Average Period before Ambulation: With Restricted Activities (*Months*)	Average Period before Ambulation: With Full Normal Activities (*Months*)
Tibia (121 cases)				
By choice	51	50	1	4.5
By necessity	10	10	2.5	4.8
Compound fractures	60	57	2.4	7.7
Femur (58 cases)				
By choice	10	9	2	5
By necessity	44	43	3.7	6.4
Compound fractures	4	3	4	8

infections resulting in amputation. Three infections, two of which occurred after early fracture of the plate in cases with postoperative immobilization, resulted in local osteomyelitis, but did not prevent bony union of the fractures. Five trivial infections, involving only the skin or superficial tissues, occurred. The remainder of the operative incisions healed by first intention. Sixty-three simple fractures of the tibia were operated upon. Two infections, resulting in localized osteomyelitis but not preventing bony union, occurred. One trivial infection of the superficial tissues occurred. In the remaining cases healing was uneventful.

Anatomical Results

Ability to maintain the length and axis of a fractured long bone, even in the presence of extensive comminution or actual loss of substance, is one of the important advantages of internal fixation. In all the cases herein reported, these two anatomical features were measured by both clinical and roentgenographic examination of the late results (Table V). Some of the twenty-seven slight angular deformities, visible only by roentgenogram, undoubtedly were contributed to by maintenance of motion throughout the period of healing and by protected weight-bearing prior to bony union. Many of them, however, resulted from faulty operative technique and were present in the roentgenogram immediately after operation. None of them caused trouble or were appreciated by the patient.

Range of Motion in Adjacent Joints

In all cases treated by open reduction and internal fixation as the method of choice, and in as many of the others as was possible and safe, maintenance of joint motion and muscle action throughout the healing period was the aim of the postoperative program At times this objective was precluded by concomitant injuries, systemic complications, or defective fixation, requiring supplemental external immobilization Table VI shows the end-result motion in the joints adjacent to the fracture The patients having normal motion maintained an essentially full range from the start, and did not require a specific rehabilitation program to mobilize the involved joints following healing of the fracture

Symptoms

As mentioned previously, localized pain or tenderness, requiring late removal of the means of internal fixation, developed in a certain number of cases In some of these, nothing was found to account for the local symptoms Electrolytic reaction between the fixation material and the tissues was present in others Soft tissues, moving constantly over the surface of the fixation, occasionally resulted in the formation of an adventitious bursa which became painful Subcutaneous fixation usually required eventual removal, because of local tenderness or pain An analysis of the end-result symptoms is given in Table VII

Time of Economic Rehabilitation and Disability

Of the 179 fractures reported, 113 had end results completely normal to both subjective and objective evaluation If to these are added the twenty-seven cases rated less than perfect, because of a slight angular deformity, visible by x-ray but not discernible by clinical examination (Table V), 140 end results approximated normal Information as to the patients' recovery of their former economic status is shown in Table VIII

CONCLUSIONS

The use of open reduction and internal fixation, by choice, is vindicated in selected fractures of the shafts of the tibia and femur, and in certain compound fractures of these bones In this study, good results were found to be much more dependent upon the way the materials for internal fixation were used than upon their composition Fixation rigid enough to make possible a maintenance of physiological function throughout healing most nearly accomplished the primary aim of all fracture therapy,—to restore the patient to his usual activities as soon as possible and in a condition as nearly normal as possible

DISCUSSION

Dr Mather Cleveland, New York, N Y (Chairman) Three basic methods of treatment of fractures of the long bones have been presented, and each of these authors has borrowed at least one of the methods presented here today as an adjunct in his treatment of fractures of the long bones This should indicate that no single method, which will yield satisfactory results in every instance, can be applied to all long-bone fractures We endeavored to make these presentations as nearly comparable as possible by confining the discussion to weight-bearing long bones

The fractured shaft of the femur is a grave surgical problem Robert Kennedy presented a series of 120 consecutive fractures of the femoral shaft from Beekman Street Hospital There was a mortality of 14 per cent, mostly within the first twenty-four hours From the First Surgical Division of Bellevue Hospital in New York, there was an identical mortality of 14 per cent Kennedy concluded that no single method of treatment is applicable in all instances

Dr Winant's sixty-eight patients with fractures of the femoral shaft are a selected group The mortality is zero, because the deaths occurred overseas and the hardy or fortunate survivors reached the hospitals in the Zone of the Interior Complications among these fit young men were minimal Delayed primary closure converted many of the compound fractures into simple fractures In no single instance among these compound fractures of the femur was there frank suppurative osteomyelitis Some of the wounds healed by second intention, however This represents an enormous advance over the situation which prevailed during the earlier campaigns, when patients returned from overseas with their wounds plugged with petrolatum gauze, bathed in purulent exudate Penicillin also became readily available early in 1944, and this gave the Army surgeon

some needed assurance that delayed primary closure might be successful It had been successfully accomplished twenty-five years earlier in World War I, without benefit of the antibiotics, and quite promptly forgotten

When Dr Winant speaks of patients requiring internal fixation, he is in reality dealing with those which presented problems in bone replacement

The important contribution in this paper is the verification of our firm belief that delayed primary closure may be employed with success in a large proportion of these compound fractures, and that suppurative osteomyelitis fails to develop when intact skin is restored I hope Dr Winant may be able to carry out an additional follow-up study on his patients

Dr McLaughlin's paper is a very careful and interesting analysis of 200 fractures of the tibia, fibula, and femur, treated during a twenty-year period Bony union by gradual disappearance of the fracture line, as described by the author, takes place in transcervical fractures of the femur It is quite different if there is severe comminution or marked displacement

There was an incidence of infection of a little under 5 per cent in the simple femoral fractures operated upon, and of 5 per cent in the simple fractures of the tibia Happily, none of these had disastrous results, but there is a minimal risk despite the antibiotics

These patients have been rigidly judged as to maintenance of length and motion in joints, and 73 per cent were found completely asymptomatic under the best possible conditions Patients recovered their former economic status in four and a half months after simple fractures of the tibia, with fractures of the femur, five to six months were required for simple fractures and eight months for compound fractures,—an excellent record

Any series of open reductions of the femur is bound to represent a picked group, in that the immediate mortality has been screened out In Dr McLaughlin's series of sixty-three fractures of the femur, no mortality occurred

I agree that technique is more important than metallurgy Dr McLaughlin stressed that proper selection of patients for open reduction is necessary to obtain optimum results in fractures of the weight-bearing bones

Mr H Osmond Clarke, London, England I believe that the surgeon who treats fractures should have every facility at his command, from manual dexterity to all the complicated methods of screwing and grafting that you see today I believe the safest method for treating fractures still is to reduce them with your two hands and hold the fragments in place with a plaster-of-Paris splint In an analysis of 200 cases of fracture of the femur treated up to 1944 in Britain, the greatest difficulty we encountered was non-union, due to stretching and sometimes to infection The infection did not occur from the original wound, because that was usually so adequately treated that it healed in a very short time The sepsis we had to deal with was introduced by the surgeon I believe you should treat these fractures conservatively if possible If not you should operate but only under the most ideal conditions of bone surgery If those conditions are not available, it is far better to wrap the fracture in plaster-of-Paris or some other form of splinting and send the patient to a center for fracture treatment

The best treatment is by conservative methods, with the fracture held by simple means until it has united, and immobilization of all the joints until union has occurred

Dr H Earle Conwell, Birmingham, Alabama Dr Winant has presented an excellent analysis of a properly supervised group of cases The results show that skeletal traction is still the method of choice in most compound, severely traumatized fractures of the long bones, especially of the femur,—that is, in cases where the soft-structure damage is so severe that the bone and tissues could not withstand even the minimum trauma of an open internal fixation, or in those cases with such comminution that sufficiently large bone fragments are not present for the application of internal fixation Dr Winant failed to classify the soft-structure damage which is so frequently neglected in reports on fracture treatment

Twenty-four years ago, I reported a series of 100 cases with fractures of the shaft of the femur, treated by skeletal traction, 50 per cent were compound fractures, with an average soft-tissue damage of three plus In this series only two had non-union which demanded open internal fixation, and these two were cases of compound fracture In none of the compound fractures was there any severe infection This was before the days of penicillin and the sulfonamides, but not before good surgical débridement was being practised I have continued this treatment in such cases with results as good as, if not better than, those obtained by other methods It is needless to mention that the surgical technique today should not be any less meticulous just because we have penicillin and sulfonamides, but often too much confidence is placed in these agents and surgical technique is neglected I have always advocated the importance of good surgical débridement, and of mechanical cleansing and early closure of the wound

For years I have treated all compound fractures of the femur by an overhead frame, with the lower extremity in the 90-90-90 position which was used in World War II This position—that is, a right-angled flexion of the thigh at the hip and of the leg at the knee joint—makes compound wounds very accessible for dressing and inspection of the extremity

For fractures through the upper two-thirds of the shaft of the femur, I prefer skeletal traction through the lower fourth of the femur, while for those in the lower third of the femoral shaft, I prefer skeletal traction through the upper fourth of the tibia

Skeletal traction demands as good surgical technique in its application and convalescent observation as open reduction It should not be applied or supervised by the inexperienced doctor, and, in most instances, it should be applied under general anaesthesia so that a real attempt at early closed reduction with muscle relaxation can be made

The small Kirschner wire is far superior to the Steinmann pin for use in traction Less trauma is done to the bone and surrounding tissues by using a Kirschner wire of average size

Internal fixation in selected cases of fracture of the femur, as in any other fracture, should be done at an early stage when necessary, and the surgeon should be capable of selecting such a case early in its history I am doing more internal fixations on simple transverse fractures of the femur with minimum soft-structure injury today than ever

In order to present a fault of internal pin fixation (one example being the intramedullary pin advocated by Küntscher and others), I wish to say that the intramedullary peg was discarded years ago I refer particularly to the beef-bone peg used by Hendon and the cow-horn peg used by Fowler and others The objection to such intramedullary peg fixation was that it produced too much trauma to the vital bone-healing area at the fracture site, causing non-union in a large percentage of cases Too often such treatment requires a more radical surgical approach than does simple internal fixation A complicated fracture results, and more trauma is produced than by doing a simple open internal fixation Let's not be misled by a fadist treatment, but deal with each case as an individual problem, and apply the treatment to the fracture and not the fracture to the treatment.

Osteomyelitis is an inevitable occurrence of the indiscriminate or indiscreet use of external pin fixation I use such technique in a few selected cases

Probably no other fracture clinic could make such an authentic report of results as Dr McLaughlin and his associates have presented I have observed for many years the rigid doctrine and practice of Dr Clay Ray Murray and Dr William Darrach in doing open reductions and internal fixation Their set-up is ideal We can never replace that personal factor in medicine, and we must ever be conscious of the fact that the Master makes the tools and not vice versa

In the fresh fractures in our Clinic, we are averaging about 5 per cent of open reductions with internal fixation We feel that if an average of over 10 per cent of open reductions occurs in a fracture clinic—that is, in fresh fractures—too many open reductions are being done and the practice of closed manipulation and reduction is being neglected Our results by the closed method have been excellent, however, the case which demands open reduction and internal fixation should have early attention and proper mechanical fixation with the proper metal By so doing, the best results will be obtained

Dr McLaughlin's report demands deep consideration before the technique presented is carried out First, analyze yourself as follows How good a surgeon are you? Do you know damaged tissue when you see it? Have you a proper set-up and well-trained assistants? Were you trained to do most of your work by the open or closed method? Last but not least, remember that a surgeon is not one who incises and thinks, but one who first thinks and reasons and in most instances does not incise Dr McLaughlin's presentation is for individual consumption and not for general distribution

Dr R I Harris, Toronto, Ontario, Canada Dr Cleveland deserves our thanks in that he has planned this symposium around a discussion of the principles of treatment We have listened to papers on the principle of open reduction and internal fixation, we have listened to a paper on the principle of traction, and we have listened to a paper on the benefits of external skeletal fixation * Fractures, however, do not lend themselves to complete regimentation, as is the case in other fields of surgery, because they differ profoundly one from another, even in the same bone What is successful in the management of one fracture may not be successful in the treatment of another, because of differences in the fractures themselves Moreover, the application of methods of treatment of fractures will vary from place to place and from individual to individual Many fractures demand for their best treatment more or less elaborate apparatus, the highest technical equipment from hospitals, the greatest skill in the use of that technical equipment, and experience and skill on the part of the surgeons, but fractures do not always occur in places or under circumstances where these things are available Therefore, what is justifiable in the hands of a trained surgeon in one place in a properly equipped hospital is entirely unjustifiable elsewhere

This is one of the difficulties in the discussion of fracture treatment, particularly in terms of undergraduate and postgraduate lectures on fracture treatment Those who are concerned with undergraduate teaching frequently find themselves teaching one form of fracture treatment and practising something different That is because they are skilled fracture surgeons and are justified in using methods which they would not be justi-

* By John R Naden, M D Paper not received in time for publication in this iss

CRITICAL OBSERVATIONS OF THE RESULTS IN THE OPERATIVE TREATMENT OF SCOLIOSIS *

BY WILLIAM H. VON LACKUM, M.D., AND J. P. MILLER, M.D., NEW YORK, N. Y.

From the New York Orthopaedic Dispensary and Hospital

In the past thirty-one years, over 1,500 cases of scoliosis have been treated surgically at the New York Orthopaedic Hospital, including 850 cases treated since 1928 by the Risser hinge-jacket technique.

From a study of the data compiled in an analysis of these cases, we are now in a position to outline some of the causes of the substandard results, and to present the rationale of a somewhat modified type of treatment to correct these deficiencies, which is now coming into use by our staff.

In the study of many untreated cases of scoliosis, it has been observed that practically all of these patients attain an erect posture through adaptive bone growth, the head being centered perpendicularly over the sacrum, with the shoulders and pelvis level. It is true that a few, because of insufficient spinal segments, fail to attain this perfectly balanced state, but in all of them progress has been in that direction. This response of the spine to some developmental defect or muscle anomaly is, we believe, mediated through the constant action of the nerve tracts involved in the righting reflexes, and is accomplished through constant unilateral pressure on the growing bone in the spinal segments, according to the laws of bone growth. Thus we have come to feel that the development of a scoliosis is, in essence, a protective reaction on the part of the growing spine, endeavoring to maintain the erect posture in the presence of some unbalancing force or forces.

These statements are, indeed, self-evident when we realize that it is contrary to the laws of physics for a patient to stand erectly and to walk without the body mass being placed perpendicularly over the center of the weight-bearing platform. Since the pelvis is parallel to the walking surface, through the demands of equal limb length, it follows that all spines, scoliotic or straight, must be functionally perpendicular to the ground.

In a full-grown scoliotic spine, therefore, a so-called single primary curve is necessarily balanced by two reverse curves,—one above the primary curve and one below. If perfect balance has been attained (as is usual), the sum of the two reverse curves must be equal in degree to that of the primary curve. In the so-called double primary patterns, the two equal large curves balance each other, while the high cervicothoracic curve balances the lumbosacral return to the erect. To appreciate fully the significance of the total over-all balance of the individual patient, it is necessary to analyze the spine and the individual as a whole, rather than limiting study to isolated spinal areas.

It must be constantly borne in mind that the individual vertebrae involved in scoliosis have adapted themselves and their facet articulations to a deviated position of the spine throughout their entire period of growth, and that the position they occupy is, for them, functionally normal. Consequently, the vertebrae involved have a range of lateral motion similar in degree to their counterparts in the normal spine, differing only in the fact that their motion is transposed to a deviated plane. These facts hold true for all the deviated segments in the scoliotic spine, both in the primary curves and in the curves in the reverse direction. It is a constant observation that the normal range of lateral vertebral motion is much more limited in the high thoracic region than in the lumbar area. For this reason, in the pattern of deformity of the single primary curve, we would expect the upper compensatory curve to be more resistant to spontaneous reversal after an induced correction below

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 27, 1948.

This has been found to be true in our series, and we now believe that this upper curve also requires inclusion in the correction and fusion procedure, and that it should be corrected by a similar degree

With these considerations in mind, it is evident that, when correction of a single primary curve is effected, it is a mistake to carry the correction to a degree beyond the ability of the compensatory curves to reverse themselves spontaneously When such an excessive correction is carried out, the balance toward which that patient has strived throughout the entire growth period will have been destroyed Through the use of bend and tilt tests, we have found that, in the average fully matured spine, the upper and lower compensatory curves will reverse themselves to a total of approximately 20 degrees, and the greater amount of this reversal will have been attained in the lower compensatory area Therefore, if balance is to be maintained postoperatively, it is evident that the so-called primary curve can be corrected in a mature spine by only about 20 degrees

The importance of these factors is, we believe, brought out most clearly by a study of the postoperative findings in cases that have been overcorrected in a single area If the fused area has been straightened to a degree beyond the ability of the compensatory curves to reverse themselves, and holds in its corrected position, the patient will be unbalanced, and to regain balance in order to walk erectly, he *must* lose correction in the fused area

This unbalanced state induced by operation, which has remained static and uninfluenced by any active force while the patient has been recumbent in plaster fixation, is immediately subjected to a powerful active force, the righting reflex, which asserts itself the moment the change is made to the upright posture, and locomotion, with or without a plaster jacket, is begun *A gradual but sustained loss of correction ensues,* occasionally, this undoubtedly occurs through a localized area of deficient fusion, but, as shown by repeated negative explorations, it occurs very often throughout the general immature fusion area, *without the presence of a pseudarthrosis*

In cases in which the spine was fully grown, the amount of correction lost has been directly proportional to the amount of overcorrection, and the loss has not progressed beyond the point of balance In fact, in most cases, the loss of correction proceeds to a degree which is just equal to the combined amount of reversibility in the compensatory curves, as shown by the preoperative bend and tilt tests

In the event that excessive correction has been carried out in a spine that has not completely finished its growth, an even more interesting rebalancing sequel develops If the fused segment holds in its overcorrected position, the patient is out of balance, and in the lumbar vertebrae below, which are still growing, a rapidly progressing curve develops in an effort to restore total body balance through bone growth This progression of the lumbar curve after correction and fusion above is believed to be due solely to overcorrection in the upper fused area The progress of the lumbar curve will be minimized, of course, if the overcorrection in the fused area is lost on the assumption of the position of weight-bearing

We cannot emphasize too strongly the importance of studying *all* of the spinal curves and their spontaneous reversibilities before deciding to what degree to correct the so-called primary curve Most of our difficulties have come from too much correction, rather than from too little This is especially true in scoliotic spines in which growth is not complete

From the foregoing discussion it is evident that, in the surgical treatment of scoliosis, if balance is to be maintained, the amount of correction advisable in a primary curve must be determined entirely by the precalculated spontaneous reversibility of the compensatory curves Any correction to a degree greater than this should, we believe, be accompanied by simultaneous correction and fusion of all curves in the spine Such correction must be adjusted to result in postoperative equality of the sum of the reverse curves to that of the primary curve, in each of their corrected positions

In an effort to meet the challenge offered by these observations, we have now in use a type of jacket in which several areas can be corrected simultaneously.

It is obvious that any corrective modality, to be effective to the maximum, should vary somewhat with the pattern of the individual deformity, its location and flexibility. This is possible in this type of jacket, which we have called the "transection jacket". It was designed particularly to eliminate some of the deficiencies of the hinge jacket, and has aided greatly in improving and expediting therapy.

The transection jacket is a body jacket, including both the thighs and the head. It is divided transversely into two parts, the dividing line characteristically being at the junction point of two equal curves,—at or near the lumbosacral junction in the single primary lumbar curves, and at the lower end of primary thoracic curves. This jacket has neither hinges nor turnbuckles, and correction can be accomplished at any time within an hour after the jacket has been applied. In the flexible curves, the correction is usually effected by a manual shift of one transected portion of the jacket against the other. In the more rigid deformities, the hinge jacket is preferable, or surcingles or ratchets may be used to increase the force of the transection-jacket correction. In flexible single primary curves in the lower thoracic area, corrections have more recently been made by two transverse cuts in the jacket, leaving a central portion which embraces the central primary curve. This double transection has the particular advantage of forcing the three curves into alignment simultaneously. This makes it possible to take full advantage of all the correction obtainable in the primary curve and at the same time to correct the reverse curves. In such a manner, progress of lower curves in immature, incompletely grown spines is avoided, and a correction compatible with the balance for which every scoliotic strives through growth is always obtained.

This is in sharp contrast to the limited corrections permitted by the past method of single-curve correction, which has so often subjected the primary corrected area to the deleterious effects of fixed, incompletely reversible compensatory curves.

The cases treated by means of the transection jacket have failed to show loss of correction and have been well balanced, postoperatively. Although the areas of fusion have been somewhat longer than in the cases previously treated, the clinical results have proved the advantages of this method over those previously used. These cases will be reported in detail later.

It is apparent that, in the selection of the areas for fusion, as well as in the considerations of the amount of correction sought, we have deviated from the postulates of Ferguson. Our present criteria are:

1. In single primary curves, where correction has been carried out to a degree equal to the combined reversibilities of the compensatory curves only, fusion of the primary curve alone is indicated. This applies to those cases in which any type of correction has been employed.

2. In flexible single primary curves, where the double transection jacket has been used, simultaneously and proportionally correcting all curves in balance, fusion should extend to include all the originally deviated vertebrae in their corrected positions. This more inclusive area of fusion ensures the maintenance of a proportional amount of correction in all curves, and good postoperative body balance. This technique is being applied particularly to scoliotic spines in which a considerable amount of growth is still anticipated. Since no imbalance is produced and progressive deformity has been arrested, there is no reason to expect further progress.

3. In those so-called double primary curves, where the pattern is essentially that of two opposing large curves, we employ exclusively the single transection jacket and fuse the total extent of both curves, usually from the fourth thoracic to the fourth lumbar, in order to ensure that both curves, which have been corrected symmetrically beyond their normal lateral ranges of motion, will remain in that position.

CONCLUSIONS

From recent studies of postoperative end results in the treatment of scoliosis, we have found what we believe to be the causes for substandard clinical end results We have revealed that excessive correction of single primary curves by the hinge-jacket technique has caused subsequent loss of balance As a result of the excessive correction, these primary curves of the spine have been forced to spontaneously re-establish their own body balance We have presented the several courses taken by these cases in their postoperative spontaneous return to balance, evidenced clinically in recurrent primary deviations, or in new deformities in adjacent areas of the spine

In conclusion, many of the substandard results in the hinge-jacket treatment of scoliosis at the New York Orthopaedic Hospital have been traced to excessive correction in single primary curves Further, the failure of compensatory curves to reverse spontaneously, in response to jacket correction of a single primary curve, is a consistent finding Jacket corrections which do not take into consideration multiple spine deformity and total body balance are doomed to relative failure, either by compensatory phenomena, which develop secondarily, or by loss of primary correction

Finally, more comprehensive principles of corrective therapy have done much to improve and to expedite surgical therapy The transection jacket, after four years of use on more than 100 cases, has proved a highly valuable adjunct

DISCUSSION

Dr Albert B Ferguson, Brookline, Massachusetts It has been a great pleasure to study the papers of Dr von Lackum and Dr Cobb Both contribute toward the solving of some of the difficult problems of scoliosis Both authors believe that the only effective treatment of scoliosis is correction and fusion, when it has become essential to stop progress and preserve alignment In such a case, the question is "What portion of the spine must be corrected and fused?"

In the given case, there are one or more curves which must be corrected and fused if satisfactory alignment is to be achieved and maintained, there may be one or more curves which will adjust themselves in a satisfactory manner without fusion I see no point in arguing whether we should call a curve that requires fusion a major curve or a primary curve, neither term is wholly satisfactory It would be helpful if we could agree on some term that all orthopaedic surgeons would understand

The more important question is "How can we identify these major or primary curves which must be included in a fusion?" The answer is not to be given in this short discussion Some help will be gained by the study of what has been written about primary curves by such authors as Risser, Ullrich, Smith, and myself Much help will be gained from the study of the present article by Cobb* I will take the liberty of emphasizing only one point in this connection I receive films of many cases which have had lateral bending to study passive correctibility, but very few which include a tilt test to study the power of the patient to correct the curve or curves in the lumbar and low thoracic areas I venture to state that, even though one may be able to point out a rare exception, a curve which shows full correction on the tilt test will not cause damaging disalignment after fusion of other curve or curves The test should be much more widely used, especially by those of lesser experience, as an aid in determining whether or not the lower half of the spine contains a curve or curves that do not need to be included in a contemplated fusion

The tilt test is performed by roentgenographic examination in the erect position, with the pelvis raised three or four inches, first on one side and then on the other, by a sandbag under the buttock, if sitting, or a lift under the foot, if standing

It is a fundamental principle of scoliosis that, after a deformity has been induced in one or more locations in the spine, the unaffected portions of the spine and the pelvis tend to align themselves in such a way that the body will be in balance, with the head erect over the center of the pelvis, this alignment will be attempted in the easiest possible way This important principle has not been sufficiently appreciated probably because it has been described by many cumbersome words It is, therefore, a pleasure to hear Dr von Lackum use the term "righting reflex" to express this principle briefly and pithily

Dr von Lackum has been making a serious attempt to avoid successive periods of correction and fusion for opposite curves, by means of a jacket designed for simultaneous correction of opposite curves with a single period of immobilization for fusion The achievement of a commendable result by such means will obviously be of great value in the surgical treatment of scoliosis He has used this jacket for only four years, so comparatively few cases have a three-year follow-up Distressing experience warns me that this is not long enough for the evaluation of a method of surgical treatment of scoliosis I trust that his enthusiasm for the method will

* Not yet received for publication

continue to be justified, but I shall want to hear from him again in another three or four years before I advocate the use of this jacket. The type of correction obtained is like that of the Blount brace. More time is needed to determine whether or not the jacket is better than the brace.

Dr. von Lackum has emphasized overcorrection as a cause of substandard results. Why does he emphasize "overcorrection"? How have the results obtained with the transection jacket compared with those secured by use of the Risser jacket in patients having the proper degree of correction three years after fusion?

I do not agree with all of Dr. von Lackum's theoretical considerations. For example, I think asymmetrical bone growth is overemphasized, in relation to other factors which alter alignment of the spine, and a progressing, unfused, primary or major curve is described in some of his cases as asymmetrical growth resulting from overcorrection. I shall not discuss theory; improved results are the important thing, and both authors have done a great deal to achieve that end.

Dr. Albert C. Schmidt, Milwaukee, Wisconsin: Dr. von Lackum has pointed out that it is necessary to analyze the spine and the individual as a whole, rather than limiting the study to isolated spinal areas. Too often the study is limited to the lower two thirds of the spine, occasionally without standing films. To analyze a scoliosis properly, the various curves have to be studied in relation to a line parallel to the ground.

It is my understanding that a vertebra involved in a curve has a range of lateral motion not necessarily similar in degree to its counterpart in the normal spine, but proportional to the amount of structural changes in that vertebra. It has also been my observation that, although a spine which is solidly fused does lose some of its correction, it does not necessarily increase to the combined amount of reversibility of the compensatory curves.

Dr. von Lackum states that, when excessive correction has been carried out in a spine that has not completely finished its growth, the patient is out of balance, then, in the still-growing lumbar vertebrae below, there develops a rapidly progressive curve in a direction opposite to that of the fused area,—a natural effort to restore total balance. It would seem that the compensatory curve would have to decrease, instead of increase, or there would develop another curve in the opposite direction—namely, the same direction as the fused curve—in order to restore body balance.

I have had no experience with the transection jacket; however, it appears to be very effective in the double curves, and apparently requires a much shorter period in the hospital prior to surgery than many other methods. It also avoids undue pressure on the compensatory curves.

Dr. Henry F. Ullrich, Baltimore, Maryland: Practically every essayist on scoliosis begins his paper with a statement to the effect that a study of scoliosis is very confusing. From there, he describes his concept of the deformity, leaving the reader or listener in agreement that confusion is the most constant finding. After hearing the excellent papers by Dr. von Lackum and Dr. Cobb, I wonder if it would not be possible to simplify our terms and standardize our terminology.

Certain phases of Dr. von Lackum's treatment of this deformity stand out in my mind.

First, scoliosis affects not only the entire spine, but also the entire individual. Let us keep our mind fixed on more than the so-called primary curve.

Second, the choice of patients for operation is important. It is now possible to predict what a curve will be from expected growth. Indications for operation are pain and the amount of deformity which will be present when growth has been completed.

Third, the deformity depends not only upon the curvature or curvatures themselves, but also upon the relationship of one curve to the other. Restoration of balance and trunk displacement are, therefore, even more important than curve correction *per se*.

Fourth, fusion-area selection cannot be emphasized too strongly, and we must keep in mind the simple fact that for every degree of correction there is a correct area which should be fused to restore balance. The less the correction, the longer the fusion area, and the greater the correction, the smaller the fusion area. By keeping in mind the fact that a so-called compensatory curve with structural changes can behave as a so-called primary curve, we realize that compensatory curves do not snap back to the erect the moment the tilt of the erect vertebrae of the primary curve has been removed.

In closing, I would like to emphasize the importance of balance, as compared to correction, in treatment of this deformity. The patient is more interested in balance from a cosmetic point of view than in the number of degrees of correction shown in a roentgenogram.

The transection jacket, I believe, is a valuable contribution which aims at restoring balance of the entire spine, instead of hoping for it later, as happened occasionally with use of the hinged jacket. I wonder if the extreme lateral bending at times did not aggravate the existing ridging in the vertebral bodies in compensatory curves, and in that way hinder the straightening of the unfused portion of the spine. This type of jacket tends to minimize this, and, I believe, is well worth the longer fusion area that is necessary.

Dr. Walter P. Blount, Milwaukee, Wisconsin: I ask the privilege of making two points with regard to the scoliosis brace. Dr. Schmidt and I developed this brace together. We prefer to call it the Milwaukee

(*Continued on page 140*)

RESTRICTED JAW MOTION DUE TO OSTEOCHONDROMA OF THE CORONOID PROCESS

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In 1943, the authors [1] reported two cases of osteochondroma of the coronoid process of the mandible. They pointed out that the tumor had been an unrecognized cause of progressive limitation of motion of the jaw, and that its recognition by roentgenograms taken in the usual position employed for studies of the mandible was unlikely. Special positions, to be used for more accurate detection of this condition by roentgenography, were described. As far as could be determined at that time, no previous reports of this condition had appeared in the literature, nor have any been found subsequently. The fact that four such cases have been observed within our own limited practice makes us believe that this lesion, although uncommon, occurs more frequently than is recognized. It is the purpose of this paper to report a follow-up of the original two cases, to record two additional cases, and again to call attention to the condition and the means of its recognition and correction.

CASE 1. F. K., a fifteen-year-old boy, first came to the Johns Hopkins Hospital in June 1936, complaining that painless progressive swelling of the left side of the face had been present for three years. Except for the fact that forceps had been used at birth, there was no history of trauma. He was known to have congenital syphilis. Examination showed a hard swelling, 3 by 4 centimeters in size, in the left zygomatic region. There were no signs of inflammation. The overlying skin and the movements of the jaw were normal. The Wassermann test of the blood was positive, but that of the spinal fluid was negative. Roentgenograms taken in the usual anteroposterior and lateral positions were interpreted as showing a tumor of the soft tissue, producing distortion of the coronoid process of the mandible and of the zygoma. Syphilis was considered the most probable diagnosis and intensive antisyphilitic treatment was instituted, but the swelling continued to increase in size. Limitation of the motions of the jaw was first noted in 1940, and increased progressively. At the time of readmission to the Hospital on January 15, 1942, the swelling of the left side of the face measured 6 by 4 centimeters and was bony hard. The mouth could be opened only a half inch and occlusion was imperfect. The Wassermann test was again positive. Roentgenograms taken in the usual anteroposterior and lateral positions did not define the lesion accurately, but the special positions employed by one of the authors (W. H. B.) showed a large osteochondroma (Fig. 1-B), arising from the left coronoid process and extending upward, outward, and forward, impinging on and distorting the zygoma. The bony tumor was removed (by R. T. S.), the resected zygoma was replaced by means of wire sutures, and the jaw recovered its normal motion. Convalescence was uneventful, and the patient left the Hospital on the eighth postoperative day.

In June 1947, five and one-half years later, the patient returned for examination. At this time he had no complaints, the jaw had a full range of motion and function (Fig. 1-C), and asymmetry of the face was perceptible only after close inspection. The operative scar was minimal.

CASE 2. H. P. O., a male, aged nineteen years, was admitted to the Johns Hopkins Hospital on March 29, 1942, on the service of Dr. George E. Bennett, complaining that limitation of motion of the jaw had been present for two years. The disability had previously been attributed to impacted wisdom teeth; these had been extracted in another city, followed by a subsequent severe local infection, but without improvement. Wedges between the teeth had later been used without benefit, and the patient was referred to Dr. Bennett for possible temporomandibular arthroplasty. At the time of admission, prominence of the right zygoma was noted, but nothing suggestive of a tumor could be felt. There was no evidence of inflammation. The mouth could be opened only 1 centimeter, but occlusion was good. The remaining physical findings and the laboratory studies, including a Wassermann test, were normal. Roentgenograms taken in the usual anteroposterior and lateral positions were not definitive (Fig. 2-A), but those taken in the appropriate position showed an osteochondroma of the coronoid process (Fig. 2-B) with erosion of the zygoma and of the superior maxillary bone. At operation (by R. T. S.) the zygoma was resected in segments, the tumor was excised, and the fragments of zygoma were replaced by threading them on a wire like a string of beads.

The postoperative course was smooth. The patient left the Hospital on the eighth postoperative day with a full range of motion of the jaw, but with inability to wrinkle the right side of the forehead. This

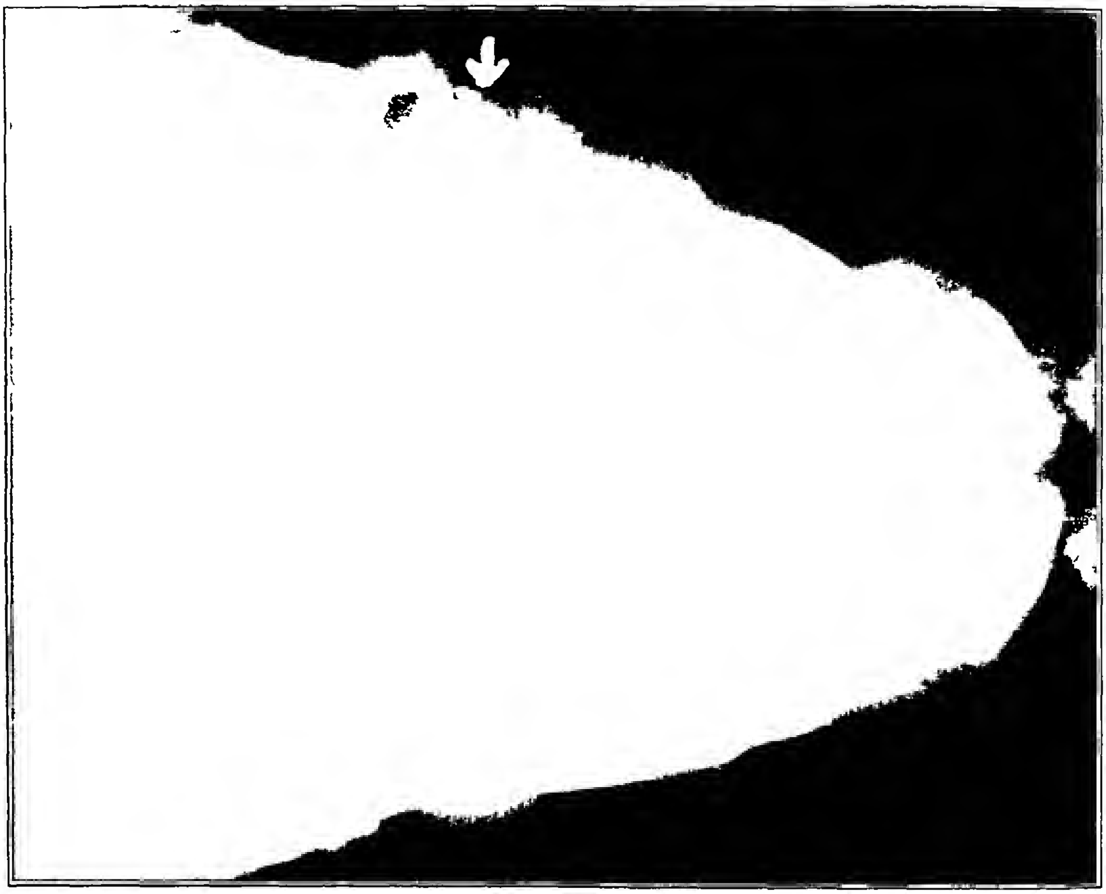

Fig 1-B

Fig 1-A

Fig. 1-A: F. K., Case 1. Preoperative roentgenogram, taken in the sinus position with the arrow showing the tumor. (Reproduced, by permission, from *Surgery, Gynecology and Obstetrics*.)

Fig. 1-B: Preoperative roentgenogram, taken in the special position, shows the tumor of the coronoid. (Arrow points to the tumor.)

Fig. 1-C: Photograph, taken five years later, shows full range of motion of the jaw as well as only slightly perceptible asymmetry of the face.

Fig. 1-C

condition persisted for several months, but then returned to normal. Within a year after his operation he was accepted in the Marine Corps, and served as an officer until the end of the War.

In May 1947, the patient returned for examination; at that time the range of motion and function of the jaw were normal, there was no perceptible asymmetry of the face, and the operative scar was minimal.

CASE 3. S. K., a man, thirty-eight years old, was referred to Dr. George E. Bennett on March 6, 1945, because of a cracking sensation in the right jaw when he opened and closed his mouth. This had been present for five years. In addition, the patient had noted that for the preceding two years the right side of his face had become increasingly swollen and motion of the jaw was becoming progressively limited. He had consulted many physicians during this time, without a diagnosis having been established.

When admitted to the Johns Hopkins Hospital on March 7, 1945, the right cheek was swollen and bony hard. Ability to open the jaw was noticeably limited and, when attempted, crepitation was palpable in the region of the right temperomandibular joint. The Wassermann reaction was negative. Roentgenograms (Fig. 3), taken in an oblique position, showed osteochondroma of the coronoid process of the right mandible.

On March 8, 1945, Dr. Bennett removed the tumor by the operative method to be described here (Fig. 5), but did not replace the resected section of the zygoma. Convalescence was uneventful and the patient left the Hospital on the seventh postoperative day. At that time motion of the jaw had returned to normal, and the crepitant noise had disappeared. He was examined on January 1, 1948, at which time the motion and function of the jaw were normal, the operative scar was minimal, and he had no complaints.

CASE 4. G. D., a white male, fifty-one years old, was admitted to the Veterans Administration Hospital at Fort Howard, Maryland, on February 28, 1945, for an unrelated condition. A routine history disclosed that in August 1943, two years before, he had been struck in the left side of the face and jaw by a passing truck. Since that time he had had a cracking noise in his jaw when he opened and closed his mouth, and had also noted increasing limitation of motion in carrying out this function. Examination showed fullness of the left zygomatic region as compared to the right, and he was unable to open the left side of the jaw as widely as the right.

Roentgenographic examination (Fig. 4) (by Dr. John T. Bracken, Jr.) in the anteroposterior sinus position showed fragmented hyperostosis in the region of the coronoid process of the left mandible, with an exostosis of the coronoid impinging on the medial surface of the zygomatic arch. There was some irregularity of the posterior surface of the zygoma, suggesting an old fracture. The Wassermann test was negative.

On May 18, 1945, an incision was made at a right angle to the left zygoma, one inch anterior to the left auditory meatus, and carried down to the zygoma. A three-quarter-inch section of zygoma was removed, and a bony tumor, which was fused with the zygoma on its posterior surface and which impinged on the coronoid process, was excised. After excision, the coronoid process moved freely when the jaw was opened and closed. No attempt was made to replace the resected segment of zygoma, and the wound was closed in layers. Convalescence was uneventful; the patient was well when last seen, at the time of his discharge from the Hospital.

The last case differed from the others in that the tumor was osseous rather than an osteochondroma, it arose from the zygoma instead of the coronoid, and followed a definite history of trauma with roentgenographic evidence of previous fracture of the zygoma. However, it is included because, due to its impingement on the coronoid process, it caused the same symptoms of progressive limitation of motion of the jaw.

The first three specimens were reported by the pathologist as being typical of osteochondroma, with stalks of bone capped by a mushroom-like head of cartilage. They were located at the site of attachment of the tendon supplying traction at that point,—namely,

Fig 2-A

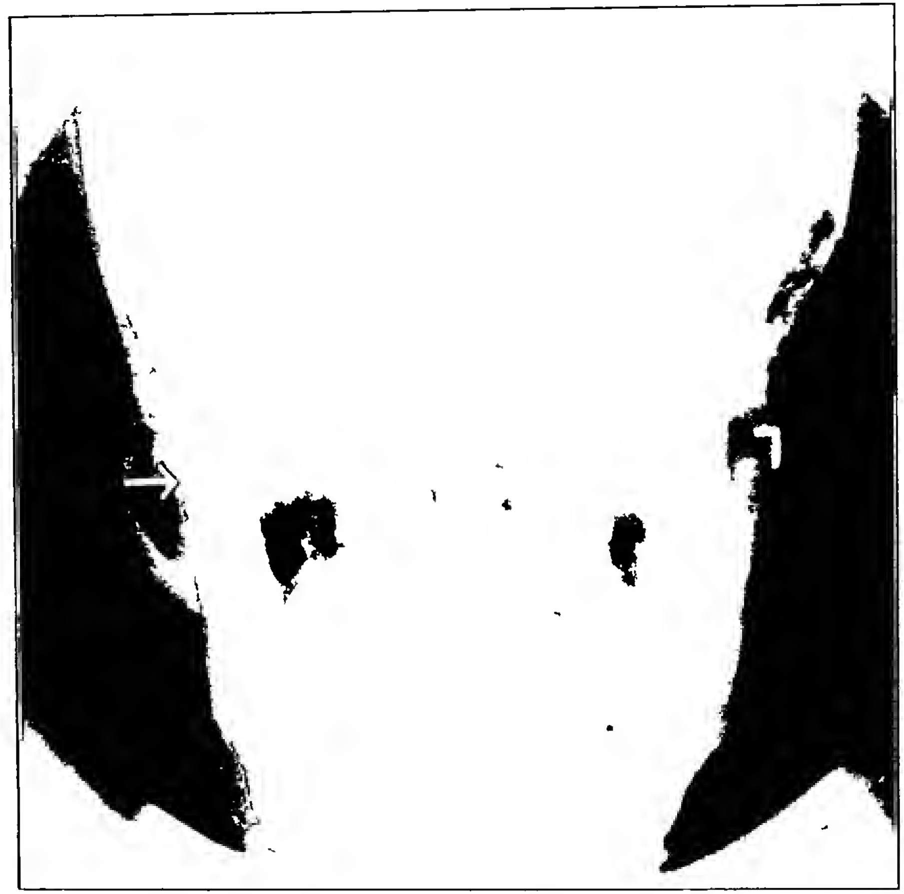

Fig 2-B

Fig 2-A H P O Case 2 Preoperative roentgenogram taken in the sinus position, with arrow pointing to the tumor

Fig 2-B Preoperative roentgenogram of the jaw, taken in the special position, reveals the tumor (Reproduced, by permission, from *Surgery, Gynecology, and Obstetrics*)

Fig 3

S K Case 3 Preoperative roentgenogram, taken in the lateral oblique position, with the arrow pointing to the tumor (This roentgenogram has been reversed)

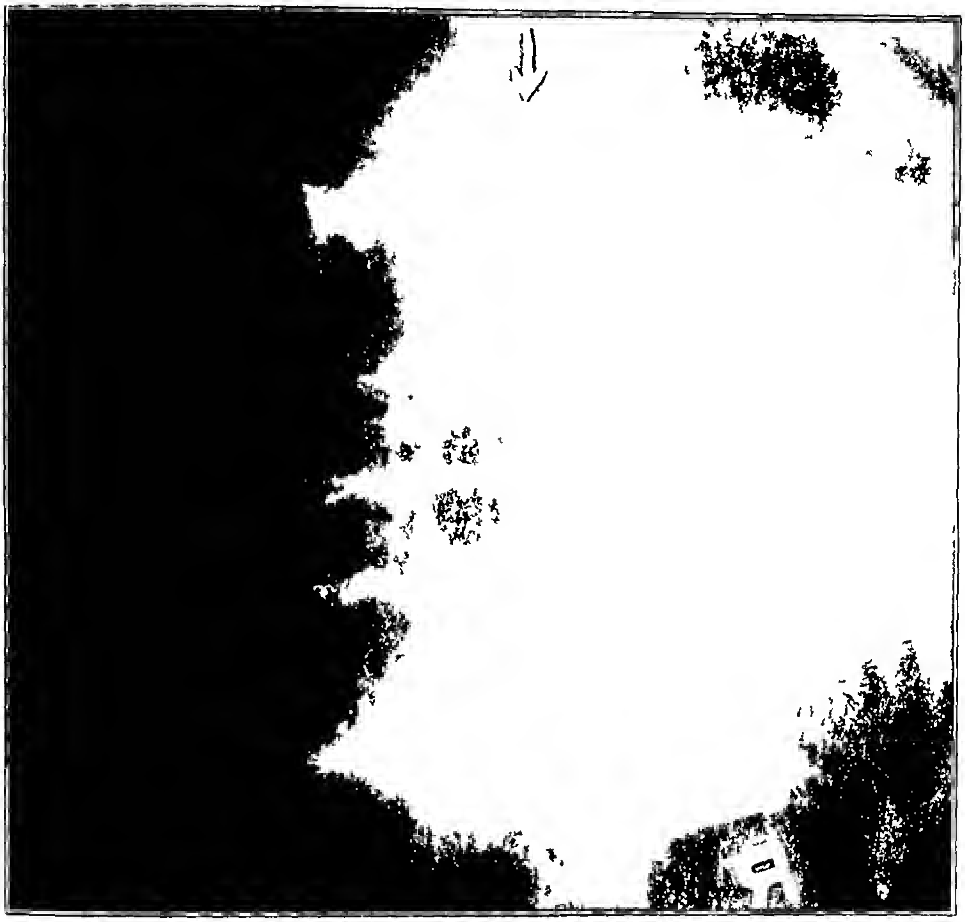

Fig 4

G D Case 4 Preoperative roentgenogram, taken in the anteroposterior position, with the arrow pointing to the tumor

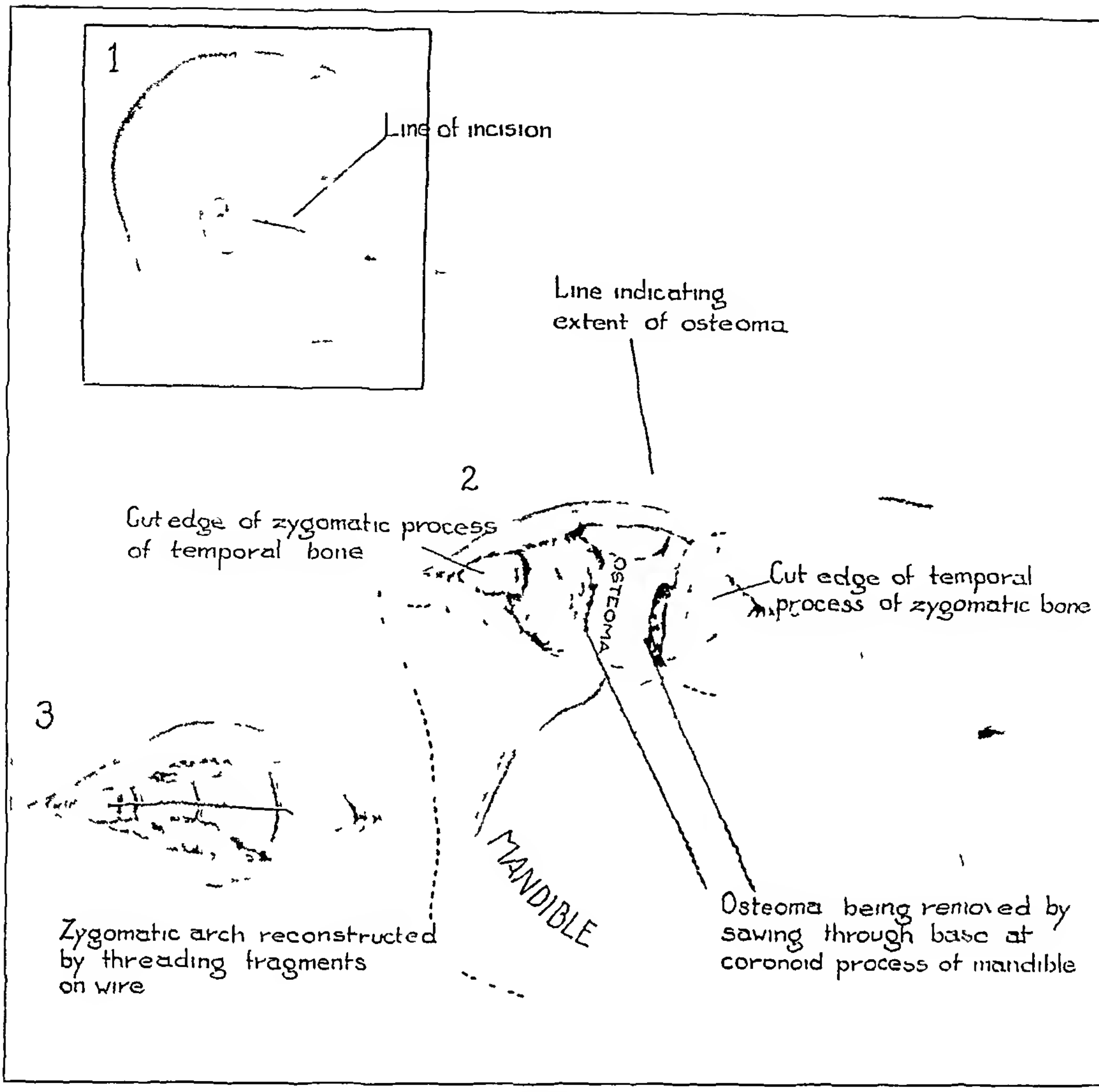

Fig 5

Steps in surgical removal of osteochondroma of coronoid process (Reproduced, by permission, from *Surgery, Gynecology, and Obstetrics*)

the tendinous insertion of the temporal muscle In these three cases there was no history of previous trauma, and the explanation offered is the same as that for osteochondroma in other parts of the body, where it commonly occurs at the sites of tendinous insertions Such characteristic locations are believed to be due to a defect in the periosteum at these points, permitting precartilaginous blastomata to escape or be pulled from the limiting membrane, and in time these cells produce an osteochondroma

The diagnosis of osteochondroma of the coronoid process has not been easy It was established in each of the first three cases only after several years had elapsed The important points to emphasize in the diagnosis of this condition are a slowly progressive, painless limitation of movement of the jaw, unilateral malocclusion of the teeth, a bony-hard swelling in the region of the zygoma on the affected side, and a bony projection visualized by the roentgenograms, taken in the special position to be described These positions are necessary to rule out such a lesion, as it is often not discernible in the anteroposterior and lateral positions routinely used in obtaining roentgenograms of the jaws

The position in which this lesion is best shown by roentgenography is illustrated in Figures 6-A and 6-B The important point is that the central ray is directed tangentially to the cheek of the affected side, instead of being centered on the mid-line symphysis of the chin The anteroposterior position usually employed for demonstrating the nasal sinuses may also give a good view of this lesion

Treatment consists of surgical excision of the growth. The operative procedure used (Fig. 5) is explained in detail in the authors' original article. In the first case, the resected zygoma was replaced by wiring it into place as a free graft; in the second, the zygoma had been removed in fragments and these were strung like beads on a wire across the bony defect; in the third and fourth cases, no attempt was made to replace that portion of the zygoma which had been removed. The cosmetic result was equally good in all four cases.

Injury to the facial nerve can be avoided by making the skin incision superior and parallel to the easily palpable inferior edge of the zygoma, below and parallel to which the zygomatic branch of the facial nerve courses. The incision is deepened until the zygomatic periosteum is incised at its *anterior* flange, where it begins to widen before articulating with the malar bone. The zygoma is bared subperiosteally until the amount desired for resection has been exposed. When this procedure is carried out subperiosteally, the zygomatic branch of the facial nerve is displaced out of danger inferiorly, and, if the stripping begins at the anterior portion of the zygoma and is not carried farther posterior than is necessary to resect the required segment, the temporal branch will likewise be spared as it ascends over the widened posterior squamous flange of the zygoma. This flange is posterior to the operative exposure required, and will be displaced posteriorly without harm if the operator carries the subperiosteal stripping farther toward the ear than is usually necessary. Temporary paralysis of either branch may occur if retractors are pulled too vigorously.

Ability to wrinkle the forehead was temporarily affected in two cases, but this function returned in each instance after a short lapse of time. There was no injury to the trigeminal nerve, Stensen's duct, or the oral mucous membrane. Each operation required two hours and was followed by an uneventful convalescence of seven days, during which the patient regained full range of motion of the jaw. These patients have been seen again

Fig. 6-A

Fig. 6-B

Fig. 6-A. Showing the position to be used in taking a roentgenogram that is most likely to reveal the tumor. The central ray is tangential to the cheek, instead of being focused in the mid-line of the chin.
Fig. 6-B. The same position as used for Fig. 6-A, but with the photograph being taken from the side.

after intervals of from two to five years, and they have normal function of the jaw, symmetry of the face, and no sign of recurrence

CONCLUSION

Progressive limitation of motion of the jaw can be caused by osteochondroma of the coronoid process of the mandible or by a bony growth in the zygoma A special position for roentgenography may be necessary to demonstrate this lesion The operative procedure described here has proved to be satisfactory

1 SHACKELFORD, R T, and BROWN, W H Osteochondroma of the Coronoid Process of the Mandible Surg, Gynec, and Obstet, 77 51-54, 1943

DISCUSSION

INTERNAL FIXATION OF FRACTURES OF THE LONG BONES

(*Continued from page 101*)

fied in teaching to their undergraduate students This is important, and I am happy to say that it has been emphasized before in this symposium Many fractures will be treated by men who are only occasional fracture surgeons That is obvious from the very nature of fractures and how they occur

In a discussion of fractures and their treatment, we must bear in mind these modifying factors Mr Clarke summed the situation up well when he said that the simplest method by and large is the best I could modify it a little by saying that the simplest method which will produce the best results, in regard to the type of fracture, the place in which it must be treated, the circumstances under which it must be treated, and the surgeon who will treat it, is the method which should be used Closed methods are preferred If open methods are necessary, then those should be used which close the wound after reduction, and other methods of internal fixation which leave no pins protruding

There is no single method of treating fractures They must be thought of as individual problems, according to the environment in which they will be treated and the persons who treat them

DR WALTER G STUCK, SAN ANTONIO, TEXAS As far as Dr Winant's paper is concerned, I think he should have listed it as a description of "war" fractures He is talking about severe injuries which were incurred overseas in patients who were transferred from hospital to hospital His results were good with skeletal traction, but fair comparisons cannot be made between these cases and a similar series in civilian practice

In the Presbyterian Hospital, with its superior staff and equipment, open reduction and internal fixation of fractures can be a successful common procedure, as Dr McLaughlin has demonstrated With the rest of us who are treating fractures in small private hospitals, it is essential that we continue our conservatism

DR EDWARD M WINANT (closing) There is no doubt that where successful primary closure of wounds has been carried out, more definitive surgery can be undertaken, when necessary, in the treatment of these compound fractures Dr Conwell's use of the Thomas splint and Pearson extension apparatus apparently allowed freer knee motion than we were permitting I believe that soft-tissue damage is important and should be evaluated, since it influences the end result Whereas it was not recorded in this series of cases, it was taken into consideration in carrying out the treatment of these fractures

One more precaution, which has been mentioned by Dr Cleveland, is that great care should be taken in not depleting these compound, comminuted fractures of their bone fragments at the time of débridement and delayed primary closure

DR HARRISON L MCLAUGHLIN (closing) Open reduction with internal fixation was not advanced in my paper as *the* method of choice It was advanced as *a* method of choice in selected cases

I would like to answer Dr Conwell According to stated statistics, I believe the incidence of open reduction on our Service is just about the same as on his If on our Service in over twenty years we have operated on only 200 fractures of the shafts of the tibia and femur, of which only about sixty-one were done as a method of choice, it indicates that a patient has a reasonable chance of entering the Presbyterian Hospital in New York with a fracture of the leg and escaping without an open reduction

CONGENITAL COXA VARA*

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Any decrease in the angle formed by the femoral neck with the femoral shaft is referred to as coxa vara[21]. Acquired coxa vara is a common deformity and may be due to a variety of causes. Congenital coxa vara is relatively infrequent and of unknown etiology. It occurs sufficiently often, however, to make its recognition as a distinct clinical entity most important. The authors propose, therefore, to summarize the current concepts of this deformity, to differentiate it from multiple congenital deformities, and to report fifteen cases.

Some confusion has arisen regarding congenital coxa vara, as evidenced by the following titles under which it has been described: "so called congenital coxa vara"[8,44], "infantile coxa vara"[1,2,7,30,44], and "developmental coxa vara"[11]. These authors are all referring to a lesion best defined by Fairbank[14] as "a form of coxa vara occurring in children and associated with radiographic changes in the neck of the femur which are sufficiently characteristic to distinguish it from all the other types of this deformity". It is this lesion, characterized by a vertical fissure in the femoral neck[33], with which this paper is concerned.

REVIEW OF THE LITERATURE

In the year 1881, disabilities of the hip were still being considered as tuberculous or non-tuberculous, and congenital dislocation was one of the more popular non-tuberculous diagnoses. Fiorani, in that year, found fifteen cases in which previously a diagnosis of congenital dislocation had been made, and concluded that this rare form of limping was in effect due to a bending of the femoral neck. Little attention was attracted by his article, but Muller, in 1888, gave the first full anatomical description of coxa vara[12]; however, the condition he described was apparently an epiphyseal separation[42]. Hofmeister, in 1894, is generally given credit for coining the term "coxa vara"[41,42]. Finally, in 1896, Kredel gave the first detailed description of congenital coxa vara[3,26,44]. Zadek has given a careful review of the early articles describing this condition.

In 1899, Whitman made an impassioned plea for a more careful classification of coxa vara on the basis of etiology. As though in answer to this paper, Hoffa, in 1905, published his now famous monograph in which he reported two cases, undoubtedly congenital coxa vara, and included the first report of the microscopic pathological findings of the lesion in the femoral neck.

The period from 1905 to 1913 is characterized by a series of isolated case reports and two outstanding papers. Delitala reported one case and included a detailed account of the microscopic pathological findings. This was the second such report. Fairbank[14] states that Elmslie, in reporting on two gross specimens, was the first to recommend designating congenital coxa vara as "infantile coxa vara". Although this term has much to recommend it, it unfortunately has not been universally adopted.

* Abridgment of thesis submitted by Dr. Babb to the faculty of the Graduate School of the University of Minnesota, in partial fulfillment of the requirements for the degree of Master of Science in Orthopedic Surgery.

From 1913 to 1924, very little was written on this subject Then, in 1924, Nilsonne reviewed the literature and reported five cases, he was the first to suggest an embryonic vascular disorder as the etiological factor in congenital coxa vara

In 1926, Noble and Hauser, in a very comprehensive paper on coxa vara in general, gave an excellent description of congenital coxa vara They attempted to solve the confusion on the subject by including all varieties of coxa vara present at birth under the term "congenital", and then dividing them into four types on the basis of additional aplasia of the femur and the presence or absence of other congenital deformities

Fairbank, in 1927, had the misfortune to have a patient die on the operating table, of a massive pulmonary thrombosis Subsequent examination of the hip disclosed that whereas the femoral neck was not visible on the roentgenogram, it was, in fact, intact but cartilaginous In the following year, Fairbank contributed to the Robert Jones Birthday Volume a comprehensive article on infantile coxa vara, including a discussion of the roentgenographic recognition of the deformity

In the years from 1927 through 1946, approximately seventy references to congenital coxa vara have appeared in the literature Twenty of these are in English Among the latter might be mentioned Barr's paper in 1929, in which he reported five cases, an excellent and comprehensive article by Zadek, in 1935, Ollerenshaw's presidential address to the Royal Society of Medicine, in 1938, a paper by Duncan, in 1938, in which he differentiated between congenital and developmental coxa vara and reported thirty-one cases, and Golding's paper, in 1939, in which he pointed out that the nine descriptions of microscopic pathological findings in the literature up to that date revealed nothing characteristic about this lesion Of the foreign literature, Camitz in 1934, Pouzet [34,35], and Taverniei and Pouzet, in 1934, have contributed substantially, reference to them will be made later, under the discussions of etiology and treatment Among the other articles written during this period were interesting case reports [1,10,13,19,27,28,41,43] and papers on coxa vara in general [36,38] Very little has been written on this subject since 1939, which is analogous to the situation that occurred during and immediately after World War I

ETIOLOGY

There is still no universal agreement as to the cause of congenital coxa vara Kredel and Hoffa expressed a belief that intra-uterine pressure was responsible Pouzet [35] and Duncan [11] held that the condition is the result of a developmental error Such theories can neither be proved nor criticized [29] It suffices to say that no hereditary factor has been demonstrated

Then there are theories that have not withstood investigation Rickets, which has never been shown to be coexistent with congenital coxa vara, can hardly be responsible Trauma can be excluded, according to Hoffa, because of the unusual number of cases of bilateral lesions Bohm suggested an atavistic theory, but Herz denied this because an examination showed that the angle of inclination of simians was not much less than that of man

Walmsley, in a careful investigation of the upper femoral epiphysis, proposed the theory of a separately ossified diaphyseal spur There is no doubt but that such a theory would account for the characteristic triangular fragment, to be described later, but how this theory would explain the more severe cases, in which the femoral neck is almost completely cartilaginous, is hard to understand

Nilsonne, in 1924, presented what is perhaps the most attractive etiological theory,— that of an embryonic vascular disturbance Camitz, in 1934, after examining microscopic sections, concluded that it was impossible histologically to distinguish between osteochondritis juvenilis (coxa plana) and so-called congenital coxa vara Nilsonne's theory and Camitz' observations would seem to coincide in the postulation of a plausible explanation of the phenomena observed in this lesion Since the femoral neck is not completely

ossified until the child is at least four years of age [12], even a postnatal vascular disturbance would explain the subsequent findings. Piergrossi, in 1939, in support of this hypothesis, demonstrated Bertolotti's metaphysitis as an evolutionary stage in congenital coxa vara. Duncan [10] supported this theory, and many of those who advocated the term "infantile" or "developmental" instead of "congenital" [1,2,39,44] appeared to be in favor of it.

This modern tendency to explain congenital coxa vara as an aseptic necrosis [18] makes it all the more essential that the condition be separated from other obvious congenital deformities. An attempt will also be made to demonstrate pathologically that the coxa vara occurring as one of multiple congenital deformities is not the same as this infantile lesion, the cause of which may even be postnatal.

PATHOLOGICAL CHANGES

Noble and Hauser state that, at birth, the upper end of the femur is a mass of cartilage. There is a single, transverse, ascending edge of ossification which, during the fourth year, reaches the upper border of the neck. The neck, being completely ossified at the fourth year, separates the capital epiphysis appearing at twelve months from that for the greater trochanter, which begins to ossify only in the fourth year. Any disturbance of ossification of the neck, therefore, must occur in the first four years of life.

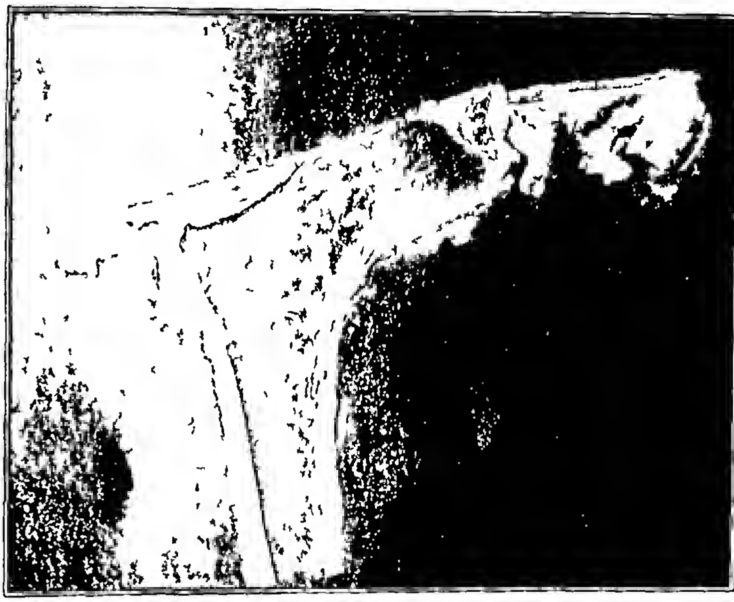

Fig. 1-A

Illustrative case of multiple congenital deformities of bones, including coxa vara. Coronal section through hip joint.

The earliest stages of congenital coxa vara are seldom seen. Ollerenshaw was shown by Herzog roentgenograms illustrating "small areas of rarefaction in the femoral neck" which apparently coalesced to produce the typical fissure, seldom evident before two years of age. By the fifth or sixth year of life, the femoral head has definitely slipped down, and the vertical fissure lateral to the epiphysis separates it from the remainder of the neck. What appears to be the head is in reality the anatomical head, the epiphyseal cartilage, and a triangular fragment of the neck, as will be demonstrated roentgenographically.

This descent of the head, then, due to a defect in the femoral neck, constitutes the gross pathological change, except for the more than occasional coexistence of a short femur. Shortening of the femur occurs at the upper end and appears to be a manifestation of an aplasia that is the result of some common underlying disturbance in ossification, as discussed in a preceding part of this paper. Such characteristics as a vertically displaced epiphyseal line and anteversion of the neck are roentgenographic features not so evident in gross pathological specimens.

Descriptions of the microscopic pathological appearance of the defect in the femoral neck have been given by Hoffa, Elmslie, Delitala, Nilsonne, Camitz, Barr, Zadek, and Duncan [11]. There is nothing characteristic in the microscopic appearance of tissue removed from the femoral neck [3,8,11]. Barr reported finding the inclusion of embryonic cartilage in normal bone, and the occurrence of non-calcified osteoid tissue has been reported

FIG 1-B
Section through epiphysis (× 35)

FIG 1-C
Section through mid-cervical region (× 6)

by Noble and Hauser Otherwise, little can apparently be said about the microscopic pathology Therefore, in an attempt to arrive at a fundamental pathological criterion for congenital coxa vara as herein defined, we can say that it is a lesion of the upper end of the femur with an incompletely ossified segment in the neck, it is composed of cartilage and osteoid tissue, and it sometimes includes gross aplasia of the upper femoral diaphysis

The coexistence of multiple congenital deformities of other bones and coxa vara constitutes the differential problem In an attempt to determine whether or not coxa vara in this relationship satisfies the pathological criterion laid down previously, such a case was investigated

A white girl, aged eight years, was first seen at the Mayo Clinic in September 1928 Examination revealed multiple congenital deformities, including club-feet, flexion deformities of both knees and both hips, and bilateral coxa vara Spina bifida occulta was also present During a manipulation under anaesthesia in January 1929, the child suddenly experienced severe respiratory distress and died shortly afterward At necropsy, death was found to have been due to fat embolism

The resected specimens included one hip joint, consisting of part of the innominate bone and the head, neck, and upper part of the femoral shaft This specimen had been sectioned in the coronal and horizontal planes through the middle of the head and neck Accurate reconstruction was impossible, but moderate coxa vara appeared to be present, with a coxofemoral angle of about 110 degrees No gross defect or triangular fragment was noted in the neck of the femur (Fig 1-A)

Two blocks were cut, one to include epiphyseal cartilage and the other from the mid-cervical region, including the inferior cortex and extending almost across the width of the available neck Both blocks were decalcified before they were sectioned, stained with hematoxylin and eosin, and mounted Examination revealed a normal epiphysis with normal compact and cancellous bone in the cervical region (Figs 1-B and 1-C)

It must be concluded, therefore, that since the condition did not satisfy the pathological criterion outlined previously, the case was not one of congenital coxa vara as herein defined Such an observation, if made on other such specimens whenever they are available, may help to prove that there are two types of "congenital coxa vara" in infants,—

first, a true congenital lesion accompanied by multiple other deformities, and, second, a disturbance in ossification confined to the upper portion of one or both femora

CLINICAL FINDINGS

Congenital coxa vara is usually discovered when the child starts to walk [21] If no deformity, such as a short leg, had been previously noted, the parents then become alarmed at the appearance of a painless limp Occasionally the limp is ignored and medical aid is not requested until adolescence By this time the presenting complaint is a painful limp [42], with undue fatigue

Physical examination typically reveals an otherwise normal child The limp is easily demonstrated when the child walks, and resembles that of congenital dislocation of the hip In fact, in cases of bilateral congenital coxa vara, the waddling gait and the marked lordosis are identical with those of congenital dislocation

Examination of the hip reveals measured shortening, which is considerable in those *patients with associated shortness of the femur* There is no spasm or tenderness, although abduction, internal rotation, and sometimes extension are mechanically limited [42] The greater trochanter is elevated and prominent [3], and the Trendelenburg test is positive on the involved side [42] The examining physician, suspecting a congenital dislocation, is then surprised to find that there is no telescoping of the femur and that the femoral head is still palpable beneath the pulsations of the femoral artery

As mentioned previously, no other congenital deformities are present in a typical case

ROENTGENOGRAPHIC EXAMINATION

Roentgenographic examination offers the most readily available means of studying this deformity Unless one is familiar with the condition, the correct diagnosis is usually not made The femoral neck is at once observed to be bent, so that the head is depressed and the distal part of the limb is thereby adducted [26] The epiphyseal line for the head is more vertical than it is normally, and it appears to be branched like an inverted Y [42] Brailsford states that this abnormal branch runs from the superior medial to the inferior lateral extremity of the neck, and isolates a triangular fragment in the inferior medial quadrant It is not, however, a branching of the epiphyseal line, but a "disorganised segment", sometimes referred to as the vertical fissure, in which an abnormal ossification process has resulted in a defect not unlike that seen in aseptic necrosis [18] or localized osteochondritis [6]

The greater trochanter is elevated and may have a peculiar beaked appearance The femoral head is comparatively large, somewhat translucent, and lies in the bottom of the acetabulum The acetabulum may be deformed in outline, and shallow and defective inferiorly, shadows resembling those seen in osteochondritis have been noted [42]

At first glance, such a roentgenogram suggests a fracture of the femoral neck, but Zadek has stated that such fractures are extremely rare in children When closer scrutiny discloses a short, imperfectly formed neck, with a zone of rarefaction which contains osseous nuclei and cuts off a triangular fragment [25, 43], one should have the necessary criteria for a correct diagnosis When, as occasionally happens, the femur is short, owing apparently to an extensive failure of ossification at the upper end, the diagnosis is obvious It is felt [14] that any such lesion with roentgenographic features so characteristic needs a more specific designation

The untreated lesion that is seen during adolescence or later is much more deserving of the diagnosis, "ununited fracture" In effect, this is usually the state of affairs What was originally a femoral defect has now become a complete dissolution of continuity The trochanter may be riding much higher than at first, the deficient neck may have been completely absorbed, and true telescoping of the femur may now be present The femoral head, strangely enough, is usually present and viable Not only does this late lesion re-

TABLE I

DATA IN FIFTEEN CASES OF CONGENITAL COXA VARA

Case and Sex	Hip	Admission: Date	Admission: Age (Years)	Admission: Complaint	Treatment: Age (Years)	Treatment: Procedure	Follow-up: Time after Operation (Years)	Follow-up: Remarks
1 F	R	May 1938	3	Short leg since birth Femur 4 inches short	8	High osteotomy, internal fixation	3	No pain No limp when shortening compensated Extension 180 degrees, flexion 90 degrees, abduction 0 degrees X-ray ossification complete, coxa vara only partially corrected
2 F	R L	Jan 1941	9	Painless limp Onset at age of 16 months	13 14	High wedge osteotomies, internal fixation	1½	No pain Moderate limp Extension right 180 degrees, left 180 degrees, flexion right 150 degrees, left 80 degrees, abduction right 30 degrees, left 45 degrees X-ray ossification complete, coxa vara corrected Left hip almost normal Right hip movement limited by short neck
3 F	R	Mar 1936	6	Painless limp Onset at age of 5 years	16	Modified Brackett reconstruction	1½	No pain, limp, or gross shortening Follow-up by questionnaire No complaints regarding hip
4 F	R	May 1943	15	Painless limp Femur 4½ inches short Misdiagnosed congenital dislocation at birth	16	High wedge osteotomy, internal fixation	3	No recent examination No reply to questionnaire
5 F	R	Mar 1943	2	Short leg since birth Femur 3 inches short	2½	Subtrochanteric osteotomy	3½	No pain No limp when shortening compensated Extension 180 degrees, flexion 60 degrees, abduction 50 degrees X-ray ossification complete, coxa vara corrected Excellent result
6 M	L	Oct 1939	10	Painless limp Onset at age of 2 years	10	Subtrochanteric osteotomy	7	No pain No limp X-ray ossification complete, coxa vara corrected Complete range of motion Trendelenburg negative "Good as normal" hip Excellent result
7 M	R	Aug 1939	14	Painless limp since 12 years of age, after minor injury	15	Subtrochanteric osteotomy	6	No recent examination No reply to questionnaire Good result 3 years after operation X-ray ossification complete, coxa vara corrected

TABLE I (*continued*)

8 M	R	Aug 1937	13	No complaint regarding hip Short tibia on opposite side		No operation	Age 21	No pain Slight limp Negative Trendelenburg Motions all normal except absent internal rotation Doubtful whether true congenital coxa vara
9 F (Negro)	R L	May 1930	7	Painless limp Onset at age of 2 years	7	Subtrochanteric osteotomies	16	No recent examination No reply to questionnaire "Good result until 10 years after operation"
10 M	R L	July 1928	9	Waddling gait Onset at age of 2 years		No operation		No follow-up data obtained Child had multiple congenital deformities, history of birth injury, and foetal rickets at age of 2 years Doubtful whether true congenital coxa vara
11 M	R	June 1932	11	Painless limp Onset at age of 3½ years	22	Subtrochanteric osteotomy (Brackett reconstruction impossible)	1½	No recent examination No reply to questionnaire Union and unprotected weight-bearing 6 months after operation
12 F	L	Mar 1940	7½* months	Short leg since birth Femur 1 inch short	5	Subtrochanteric osteotomy	2	No pain Slight limp Shortening 1 inch "She can run, skip, and roller-skate" X-ray ossification complete and coxa vara corrected Follow-up by questionnaire
13 M	R	Dec 1940	14	Painless limp Onset at age of 13 years	14	High osteotomy	6	No pain Moderate limp Shortening of ½ inch Motion moderately limited Follow-up by questionnaire X-ray coxa vara corrected
14 F	R L	Jan 1941	10	Waddling gait Inequality in limb length at age of 14 months		No operation	Age 16	Pain and fatigue minimal with restricted activity Motions limited 50 per cent Hip reconstruction anticipated Doubtful whether true congenital coxa vara
15 M	R	Mar 1947	9	Short limb since birth Femur 7 inches short	9	Modified Colonna reconstruction		At operation, no continuity of bone or cartilage could be demonstrated in neck region A small femoral head was found, stuck to bottom of acetabulum

who limps when walking is first attempted The findings on physical examination suggest a congenital dislocation of the hip, with shortening, high position of the trochanter, and a positive Trendelenburg test However, there is no telescoping and the femoral head is still palpable beneath the femoral vessels at the groin The roentgenogram will confirm the diagnosis if the lesion is not mistaken for an ununited fracture of the femoral head, a rare condition in children

The aim of treatment is to promote ossification in the neck of the femur and to correct any deformity already present Subtrochanteric osteotomy with wide abduction of the distal part of the limb will correct the coxa vara, and conversion of the sheering strain across the defect into a compression force along the axis of the neck promotes complete ossification in a high proportion of cases

Adolescent and adult patients with untreated lesions exhibit what amounts to non-union of the femoral neck Of the reconstructions available for such lesions, the Brackett operation is particularly suitable because of the high percentage of viable heads found at operation

The series of fifteen cases reported here is fairly representative and purposely includes four examples of unusual coxa vara (Cases 8, 10, 14, and 15), from which it would seem advisable to differentiate the specific lesion defined in this paper

It can be said, then, that congenital coxa vara as herein defined is *not* a proved congenital deformity The frequent association of this lesion with a short femur is probably due to a common etiological factor, possibly avascular necrosis Coxa vara associated with multiple congenital deformities is not the same lesion as that with which this paper is concerned Subtrochanteric osteotomy at about six to eight years of age, with wide abduction of the distal part of the limb, is the treatment of choice

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TUMORAL CALCINOSIS

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In 1934, when the first patient with tumoral calcinosis was examined by the authors, the unusual clinical and pathological process was recognized as worthy of follow-up study, and the accumulation of illustrative and clinical data was begun. From that time until the present, the authors have had under their care and observation three members of the same family of nine children, with tumoral calcinosis in various parts of their bodies. Pathological deductions have sometimes proved confusing and, since new tumors were developing from time to time in these children, the report has been delayed until the two living patients were adults. One has had no recurrence for twelve years, the other none for three years.

The term "tumoral calcinosis" has been used because of the similarity to the cases with this diagnosis reported by Alberto Inclan in June 1942. His conception of the pathology and the classification of the process coincides exactly with the findings in our cases. However, the familial features, metastatic characteristics, and autopsy findings in one of our cases add interesting data regarding this rather obscure and unusual pathological condition.

A review of the recent literature on the subject of calcinosis shows that there are two well-defined types which have been generally accepted. These were defined and described by Steinitz in 1931 as calcinosis circumscripta and calcinosis universalis. Pedersen, in 1943, gave a comprehensive bibliography of fifty-one articles on this subject, and reported that 137 cases of calcinosis circumscripta and 78 cases of calcinosis universalis had been collected from the literature.

The clinical, physical, and pathological findings of these conditions in no way fit the picture presented by Inclan. Ghormley, in his discussion of Inclan's paper, cites a family of three, one boy and two girls, who had lesions similar to those described by Inclan. Therefore, it would seem appropriate to add tumoral calcinosis as a third type. With the presentation of the authors' three cases of tumoral calcinosis, added to those of Inclan and Ghormley, a total of nine cases of tumoral calcinosis are contributed to the literature.

To differentiate these three types, each will be described briefly.

1. *Calcinosis circumscripta* usually occurs in middle-aged women at the period of the menopause. It is confined mainly to the upper limbs; small calcium deposits appear in the subcutaneous tissue of the fingers, frequently associated with Raynaud's disease, angiospastic syndrome, and scleroderma. The deposits or nodules are tender and the skin is atrophic.

2. *Calcinosis universalis* occurs in children and in older men. The deposits are widespread. They may be in the skin or in the subcutaneous, muscle, and fascial tissues; a whole muscle or a group of muscles may be involved. In children the prognosis is serious. Calcium may be deposited in the muscle interstices and connective tissue, or around nerves, fasciae, and sinews. The condition is chronic and progressive, causing local inconvenience. The patient may become more or less stiff and helpless. Some men having this condition show evidence of hypogonadism and high uric-acid retention.

3. *Tumoral calcinosis* occurs in young individuals of both sexes. There is probably a familial tendency. The tumors are large, rapidly growing to a definite, self-limited size; they usually occur in or near bursal sites, near large joints, and in connective tissue, immediately overlying bone and muscle attachments. The tumors are hard and lobulated, have fairly well-defined limitations in contour, are attached firmly to the underlying deep

structures, and may show some infiltration into the muscles. There is usually no pain, tenderness, or limitation of joint motion. There is a definite multilocular, cystic arrangement of the tumor, which has thick, rubbery walls, showing inflammatory foreign-body giant-cell reaction. Deep cystic areas are filled with calcareous material and some milky fluid. Surgical removal relieves the condition. Drainage and secondary infection, which occurred in one case, apparently aggravate metastatic calcification, and generalized amyloidosis may develop ultimately.

CASE REPORTS

CASE 1. D. D. (No. 31158) was first examined on April 27, 1934. He was a well-developed negro student, fifteen years of age, who complained of tumor-like enlargements on the posterior lateral aspects of both elbow joints. These tumors had first been noticed about two years before and had been gradually increasing in size. They were not painful, but were a noticeable deformity and he desired to have them removed.

The patient's previous health had always been good. He was one of nine children, and two brothers were similarly afflicted.

Physical examination disclosed equal-sized circumscribed tumors, about three and one-half inches (almost 9 centimeters) in diameter and two inches (5 centimeters) thick, located laterally and posteriorly, slightly above the elbow joint. On palpation, each appeared to be a semifluctuating mass, which was lobulated, slightly movable, and apparently attached to the deep soft-tissue structures. Manipulation did not cause pain, and there was no interference with elbow movement. Otherwise, the physical examination was negative.

The hemoglobin was 69 per cent., the white-blood-cell count 9,000. The urine was essentially normal. Attempted aspiration of the tumor produced nothing but blood.

On May 10, with a blood-pressure tourniquet applied to the upper arm, a posterolateral, curved longitudinal incision, seven inches (17.5 centimeters) long, was made over the right elbow region to the deep fascia. By blunt dissection, the integument was reflected from the encapsulated multi-

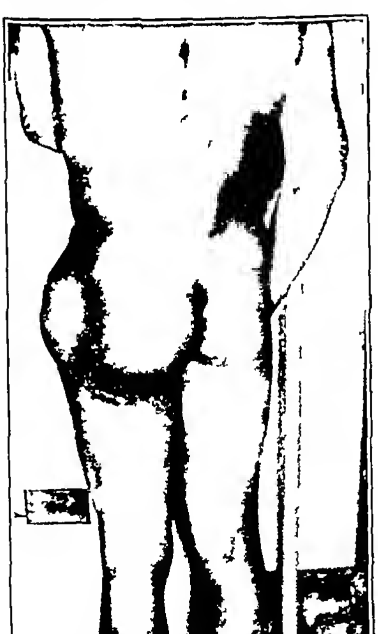

FIG. 1-A

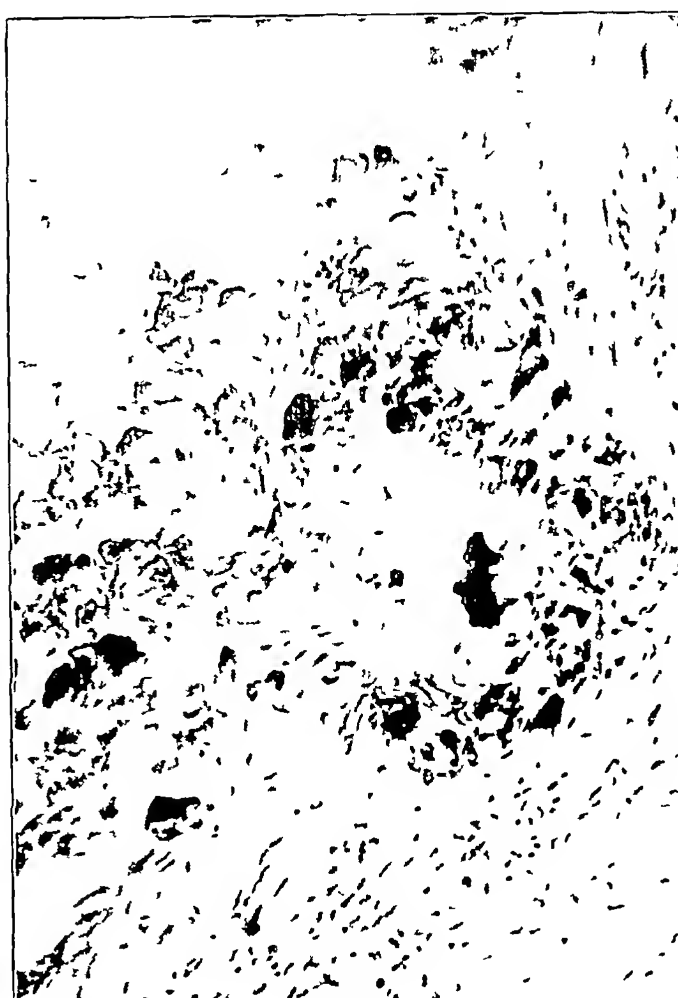

FIG. 1-B

Fig. 1-A: D. D. Tumor of left hip. There is no evidence of recurrence of tumors that were removed from elbows five years before.

Fig. 1-B: Photomicrograph (× 150) stained with hematoxylin-eosin. Tumor shows calcific deposits in fibrous stroma with a few inflammatory cells and foreign-body giant cells.

locular mass, which appeared to have its base on the lateral condyle of the humerus and to extend around posteriorly to the region of the olecranon The mass was cut through, longitudinal to the base The scalpel encountered a rubbery resistance and grating effect as it traversed the multilocular cystic wall The cut surface showed a thick-walled, granulating membrane, which was pinkish-yellow with some markedly brownish-yellow areas These cystic areas were filled with caseous or calcareous-appearing degenerating material, having a pasty consistency The base was adherent to the ligamentous structures of the posterior and lateral portions of the upper margin of the joint The capsules stripped easily from the surrounding tissues The mass did not seem to invade the muscles or tendon structures, but rather pushed them aside in its development The wound was closed after removal of the excess skin, and a pressure dressing was applied

The left elbow was similarly approached and a similar mass was removed *in toto*

Ice bags were applied to both elbows for the first forty-eight hours, and the patient had little discomfort The wounds were dressed on the third day, and 30 cubic centimeters of blood was aspirated from the incision at the right elbow On the fourth day the patient's temperature was normal and he was allowed to go home On the ninth day the sutures were removed, and he left for a Civilian Conservation Corps camp in a distant location

The specimen submitted for pathological examination measured about 5 5 centimeters in size, was slightly irregular in outline, and had a peculiar gross appearance The stroma was whitish-pink, very firm, with small cavities containing a semimucoid granular and calcific material The tumor was tough and, when cut, seemed gritty and offered increased resistance Microscopically (when reviewed in July 1945 with all material reported later) there was a fibrous stroma in which amorphous and calcific debris was deposited This debris was coarsely granular and the larger, definitely calcific masses seemed to be made up of clumps of this material Around the calcific deposits were many multinucleated giant cells and inflammatory cells Some of the cystic spaces which contained the calcific debris had synovial-like linings The foreign-body reaction and inflammatory changes appeared to be a response to the calcific deposits The diagnosis was calcinosis, involving periarticular soft tissues of the elbow (The original report, given in 1934 by M J B, was probable ruptured sebaceous cyst with secondary inflammatory reaction)

This patient was not seen again for nearly five years On January 17, 1939, he came in with a large tumor over the greater trochanter of the left femur (Fig 1-A) There had been no recurrence of the process in the elbow joints, as is evidenced by the photograph taken at the time He had no pain in the hip, but objected to the disfigurement On January 18, he was operated upon through a lateral longitudinal incision over the tumor mass This mass was the size of a man's hand, it lay under the tensor fascia muscles and extended into the muscle substance of the glutaeus maximus It was firmly adherent to the structures over the greater trochanter The tumor resembled those of the elbows The patient was in the Hospital for five days, in one week the stitches were removed, and about 50 cubic centimeters of bloody fluid was aspirated from the region Healing continued and he returned to his position

This specimen measured 15 by 8 by 5 centimeters It was grossly nodular, fibrous, and cystic, with peculiar pasty, foreign, calcific deposits The microscopic findings on review of the slide were similar to those described previously, and were typical of calcinosis (Fig 1-B) (The original diagnosis on the basis of this material had been embryonic tumor, type unknown M J B)

Case 2 R D (No 326230), brother of D D, was first seen on June 16, 1936 He was a slight negro male, aged twenty-five years, who, because of his general condition, had never been able to do manual labor or work He had been well and healthy until 1923, when a growth started on his right hip, which had gradually increased in size for about a year

The patient stated that in 1924 an abscess of the right hip had been drained, and that there had been drainage off and on since then, without pain or limitation of motion There was evidence of several incisions in the region of the hip over a large mass, which extended forward and backward, above the greater trochanter

In 1932, a mass was noted in the right elbow It had grown steadily, reaching its maximum size in about a year It had not caused pain or limitation of motion About six months later a similar tumor had begun to develop in the right axillary line, opposite the inferior angle of the scapula It had grown steadily and had extended anteriorly and posteriorly from its original site, until it covered almost the entire scapula A similar mass had started on the left shoulder, at the superior aspect of the joint, it had become quite large and protruding Others occurred on the plantar surface of the foot, on the palmar surface of the wrist, and on the right lower ribs, at the anterior axillary line All of these had grown for about a year and thereafter had not increased in size None of them had been accompanied by pain, limitation of motion, or discharge

The patient weighed 105 pounds and appeared markedly undernourished His pulse was eighty-eight, blood pressure 118 systolic and 60 diastolic, respirations twenty-two per minute On physical examination, dental caries were the only abnormal finding, except for the numerous tumors already described (Figs 2-A and 2-B) A tumor approximately 7 5 centimeters in diameter was present on the superior border of the left shoulder joint It was quite hard and immobile, and the skin was tight and stretched over it The mass did not seem to be directly connected with bone There was no limitation of motion, and no pain or discomfort

Fig 2-A

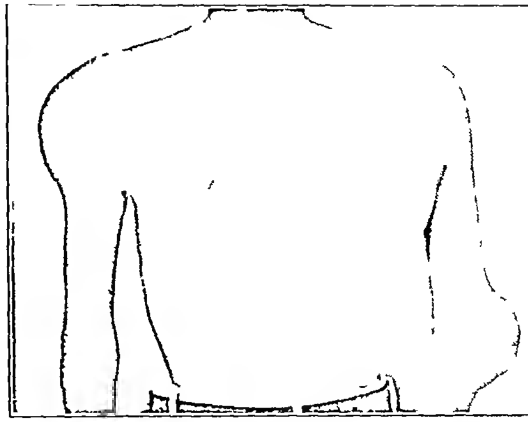

Fig 2-B

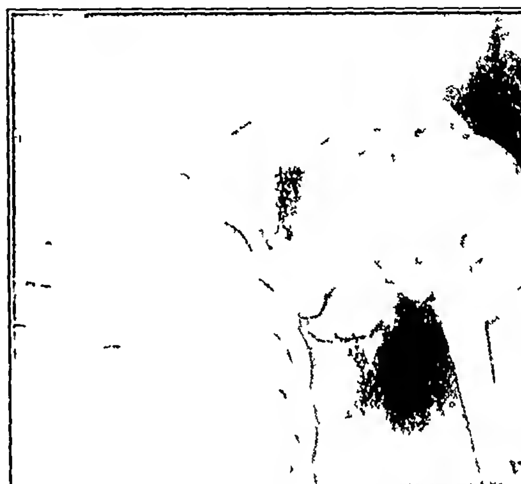

Fig 2-C

Fig 2-A R D Multiple tumors in left deltoid region, left axilla, right lower chest, right elbow, and right hip (original site)

Fig 2-B Back view shows deltoid tumor on left, large scapular tumor and elbow tumor on right

Fig 2-C Roentgenogram of left shoulder, showing extensive tumor mass in the deltoid region

The mass in the right elbow was similar in consistency to that of the shoulder, although somewhat smaller A similar mass, not very large, was seen on the lateral surface of the left hip, opposite the greater trochanter The right hip had an open, discharging lesion from a very swollen and enlarged area over the greater trochanter A small, circumscribed mass appeared on the palmar surface of the left wrist There were several scars on the thenar eminence of the hand, where the patient stated a similar mass had been present, which had broken and discharged On the left foot was a mass, 2 5 centimeters in size, on the proximal phalanx of the fourth toe, displacing the fifth toe There were masses of moderate size in both axillae, and a mass, approximately 4 3 by 8 centimeters in size, on the lower right side, in the region of the lower ribs, extending toward the axilla

At the time of admission to the Hospital, the patient's temperature was 100 The Wassermann reaction was negative

Red blood cells	3,750,000
Hemoglobin	42 per cent
White blood cells	9,600
Polymorphonuclear neutrophils	76 per cent
Bands	1
Lymphocytes	21
Mononuclears	2

On June 23, 1936, anteroposterior stereoroentgenograms of the chest showed that the costophrenic angles, the domes of the diaphragm, and both lung fields were clear The heart and great vessels were negative In the soft tissues around the chest wall were numerous rounded areas of increased density Anteroposterior roentgenograms of the left shoulder (Fig 2-C) and lower portion of the humerus showed extensive, well-demarcated accumulations of structureless material of increased density There was no evidence of bone involvement The general appearance was that of an opaque material and loculated cavities

Because of the large number of tumors and previous experience with the patient's brother, one of the authors excised the tumor of the right elbow on June 20, 1936, for further examination The specimen removed consisted of three rubbery tumor masses, the largest of which measured about 4 5 by 4 by 3 centimeters in size The surface was rough, with caseous areas and definite gross calcific deposits Review of the slides showed the microscopic picture to be identical with that previously described and to be typical of calcinosis

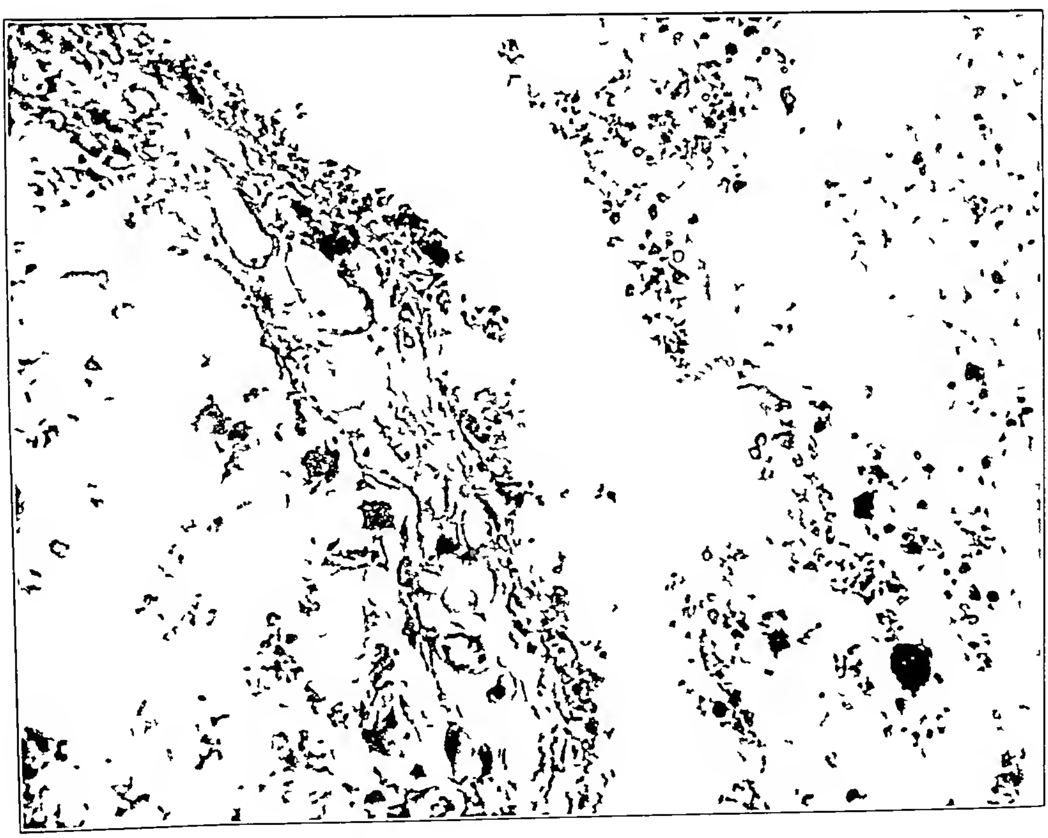

Fig 2-D

Photomicrograph (× 85) stained with hematoxylin-eosin Shows part of large cystic area, containing various-sized calcium deposits

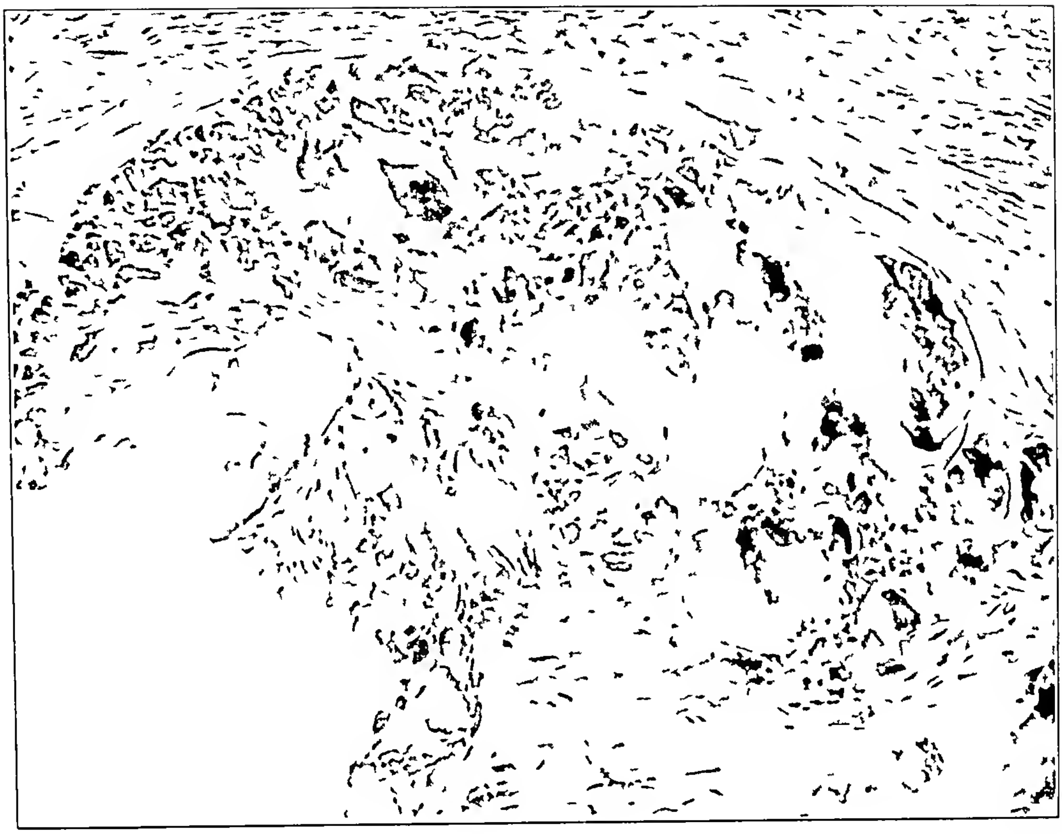

Fig 2-E

Photomicrograph (× 150) stained with hematoxylin-eosin Shows foreign-body reaction and calcific deposits in tumor

(The original diagnosis from this material by J. M. N. was of multiple periarticular giant-cell tumors.)

After consultation, it was agreed that this patient should have a period of roentgenotherapy over the involved areas. This was given, and two weeks later he was allowed to go home. A total of 1,000 roentgens was given to the left shoulder in preparation for surgical removal of the tumor, but no evidence was found of reduction in size of the mass.

The patient was not seen again until July 21, 1940, when he was admitted to the Lincoln General Hospital in a rather desperate condition. He was extremely emaciated, and had been in bed for several months because of weakness. Recently there had been acute pain in the left hip with increased swelling and fluctuation. During the last few days the pain had become unbearable, and could not be controlled by sedatives. The least movement produced a terrific paroxysm of pain. Since previous drainage had given relief, he desired immediate drainage.

Physical examination was as follows: Pulse 101 and irregular, temperature 101, and respirations 20 per minute. There was marked emaciation. The throat was injected, the tongue was coated, severe dental caries was noted, the gums were pale. The heart was enlarged in the left anterior axillary line. There was a blowing apical systolic murmur, with extension into the axilla. The entire upper portion of the thigh was tremendously swollen; a fluctuating mass could be felt in this region.

The laboratory findings were as follows:

Blood	
Hemoglobin	2.4 grams per 100 cubic centimeters (15 per cent.)
White blood cells	13,050
Polymorphonuclear neutrophils	75
Eosinophils	4
Lymphocytes	20
Monocytes	1
Urine	
pH	5.5
Specific gravity	1.011
Albumin	4 plus
Lymphocytes	1 plus
Erythrocytes	Occasional
Bile	0
Urobilinogen	0

The operative risk was recognized, and two suitable donors for postoperative transfusions were located. Because of the patient's condition, 1,000 cubic centimeters of five per cent. glucose was started with cyclopropane anaesthesia. The pulse was 120 and the blood pressure was 124 systolic and 60 diastolic. An incision for drainage was made through the fluctuating mass. Pus and debris rolled out under pressure, and a large section of the tumor mass was removed rapidly. Suddenly the patient's blood pressure dropped to 60 systolic and 20 diastolic. The wound was quickly dressed and all known restorative measures were applied, but without benefit. Oxygen, transfusion, adrenalin into the heart muscle, caffeine, and coramine were administered, but within an hour after returning to bed the man died.

Today, we realize that preoperative transfusions should have been given. However, the patient's appeals for relief of terrific pain seemed to warrant drainage. Too rapid evacuation of the cavity probably contributed to the collapse. This should have been controlled, had we contemplated such complete degeneration of the tumor.

The surgical specimen removed consisted of a large tumor mass, about 20 by 17.5 by 15 centimeters in size, but partially fragmented. The cut surface showed caseous and calcific material plus purulent debris. The microscopic sections were similar to those previously described, but with evidence of some acute inflammatory reaction. (The original diagnosis by J. M. N. was soft-tissue giant-cell tumor with superimposed inflammatory changes.)

Autopsy was performed in this case (R. D., male, twenty-nine years of age, Autopsy Protocol Lincoln General Hospital No. 1933) in 1940, a short time after removal of the tumor. The gross autopsy report originally listed as the primary findings the soft-tissue giant-cell tumors with secondary ulcerative and inflammatory changes. The gross report also included possible amyloid disease of the liver, spleen, and kidneys, congenital cysts of the kidneys, and fatty changes in the heart.

The microscopic changes, including amyloid stains with crystal violet, revealed amyloid disease of the kidneys, spleen, adrenals, and pancreas. Amyloid deposits were reported in the residual soft-tissue tumors, and it was because of this that subsequent tumors in other brothers were considered as manifestations of amyloidosis.

A complete review of the autopsy material reveals many interesting features. There is indisputable evidence of amyloid disease of the kidneys, spleen, adrenals, and pancreas. However, these changes in no way resemble the peculiar calcific deposits seen in the periarticular tumors (Figs. 2-D and 2-E). The amyloid in the visceral organs is of the usual homogenous type of infiltration around blood vessels, and is without

foreign-body reaction or inflammation This stain for amyloid is specific for that substance only in a general way, and any amorphous material deposited in tissue will take this stain to a greater degree than the adjacent viable and normal tissues The ordinary hematoxylin-eosin stains disclose a vast difference in the histological features of the tissues with the amyloid deposits and the original tissues with calcific deposits Amyloid notoriously evokes no particular reaction in the tissues, while calcium acts as a foreign body and produces the reaction seen in the original periarticular tumors

It is our opinion that the amyloid disease in the viscera was secondary to the chronic suppuration accompanying the local calcinosis Some tissues in this patient, particularly the lung, showed definite peribronchial calcific changes without amyloid In the adrenal, both were probably present as distinct entities

CASE 3 W D This boy, aged twelve, had large tumors on the backs of his elbows, similar to those of D D and that removed from R D The one on the right was discovered about one year before admission, and that on the left appeared about eight months before Both had been growing steadily, were about equal in size, and looked much like small apples There was no limitation of motion and they were not tender, but they were bothersome and disfiguring Physical examination showed nothing further of an abnormal nature His temperature was 100, pulse 100, and respirations 22 per minute The blood pressure was 105 systolic and 75 diastolic

The laboratory findings were as follows

Hemoglobin	11 grams per 100 cubic centimeters (70 per cent)
White blood cells	10,300
Polymorphonuclear neutrophils	52
Bands	3
Eosinophils	8
Basophils	1
Lymphocytes	35
Monocytes	1
Blood urea	26
Urea clearance	93 3 per cent (normal)

In the Congo red test, 90 per cent of the dye was retained in the blood, which is within normal limits, no dye was noted in one hour in the urine specimen The urine was not remarkable The sedimentation rate was 18 millimeters in one hour (Cutler method) The calcium-phosphorus ratio was 10 to 4

On May 3, 1941, both tumors were removed, recovery was uneventful The material removed consisted of three small fragments of tissue, measuring as much as 4 centimeters in diameter A light creamy "pus" was present in a fibrous and gritty stroma The review of microscopic sections showed a picture identical with that previously discussed, and typical of calcinosis (The original diagnosis in this case, by J M N, based on studies made in conjunction with the autopsy just reported, was amyloid tumor of soft tissue)

On July 23, 1945, the boy returned with a large tumor on the lateral aspect of the right hip, directly over the greater trochanter He had first noted this about six months before, after having been kicked by a horse The last two months it had increased rapidly in size It measured approximately 13 8 by 8 8 centimeters and protruded outward under the tense skin, covering about three inches One could palpate a multilocular, semifluctuating body of the tumor There was no tenderness and it did not seem to be firmly attached to the underlying structures Motions of the hip were not limited and there was no limp Nothing else of an abnormal nature was found on physical examination There was no evidence of recurrence of the tumors which had been removed from the elbow regions in 1941 X-ray examination of the hip region showed a large fluffy mass of calcium deposit or increased density over the region of the greater trochanter of the right hip (Fig 3-A) The clinical and laboratory findings yielded nothing significant On July 27, 1945, through a longitudinal incision, the tumor mass was removed It extended well up into the glutaeus maximus and down below the level of the lesser trochanter There was more extension of the process into the muscle substance than in any of the previous tumors which had been removed It was necessary to resect a considerable amount of muscle substance and to remove the tumor mass completely The wound healed by first intention and no disability followed

This specimen afforded the first opportunity for study of material from these cases by one of the authors (F H T), and initiated the review of earlier slides, as described This mass measured 9 5 centimeters in diameter and was fragmented, showing a peculiar gross tissue of whitish-pink stroma, very firm, with small cavities containing a semimucoid granular and calcific material (Fig 3-B) There were attached skeletal muscle fragments present, and grossly the tumor appeared to have invaded the muscle The tumor was tough and cut with increased gritty resistance Microscopically, the picture was exactly as described in the first case, and was considered a type of calcinosis The diagnosis was calcinosis, involving periarticular soft tissues of the hip

FIG 3-A

FIG 3-B

Fig 3-A Roentgenogram of tumor of right hip with characteristic findings of tumoral calcinosis
Fig 3-B Gross specimen from hip (9 5 centimeters in diameter before cutting) shows cut surface with fibrous stroma and small cavities containing milky and calcific debris

On May 27, 1947, we cared for this boy, who had suffered compound, comminuted fractures of the right tibia and fibula, due to having been kicked by a horse He was convalescing very satisfactorily and there had been no recurrence or evidence of calcified tumors at the original sites or elsewhere During the preceding two years he had subjected himself to all types of trauma, as he is a "broncobuster" with real ability

In summary of the pathological data, it appears that the multiple periarticular and soft-tissue tumors in these three patients are identical with one another, and that they are primarily a form of calcinosis In the one case progressing to death, ulceration to the surface with chronic suppuration occurred, and autopsy revealed definite visceral amyloidosis plus early visceral calcinosis (lungs and adrenals) While it is the authors' opinion that the amyloid disease is secondary, it is nevertheless significant because, to our knowledge, its association with calcinosis has not been reported previously Also, since so little is known about abnormal calcium deposits, the coexistence of the two may be more than coincidental

Finally, the nature of the calcinosis itself invites speculation In the absence of significant disturbances in blood chemistry, a local disturbance is most likely The possibility of aberrant localization of synovial tissue with a tissue reaction to the secreted foreign material is considered Also, the possibility of an abnormal synovial fluid in periarticular bursa with the production of a tissue irritant from the synovial membrane might be postulated

SUMMARY

Three cases of calcinosis of the tumoral type are reported The significant features are

1 The three patients with tumoral calcinosis are brothers

2 The sites of the tumors, as well as the microscopic appearance and laboratory data, were similar

3 The tumors appeared during adolescence and were self-limited in size, after growing for about one year

4 Most of the tumors arose near joints in the region of gliding surfaces or bursae, but extended into muscles

5 The tumors were fairly well defined, lobulated, and fluctuating

6 They were not accompanied by pain, tenderness, or limitation of motion

7 Complete removal seems to cure the condition locally, but similar tumors may appear elsewhere

The fatal ending in the case of R D was the result of long-standing infection, due to early secondary infection following drainage, extensive amyloid changes in the viscera, and unfortunate circumstances accompanying his critical condition when final drainage was attempted

"Tumoral calcinosis" seems to be a distinct entity of the general condition, calcinosis

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DISCUSSION

OPERATIVE TREATMENT OF SCOLIOSIS

(*Continued from page 106*)

brace, it is not the "Blount" brace When we presented the basic principles two years ago, the greatest criticism was that one cannot correct a rigid curve as far with the brace as with a bent jacket That is probably true in some cases In the material presented just now, it was shown that extreme correction is not usually desirable In our hands, the brace has never failed to obtain all of the desired correction It will do everything that the transection jacket does It is easier for the orthopaedic surgeon to use, and more comfortable for the patient to wear It will certainly correct the curves which Dr Cobb has demonstrated Dr Schmidt and I, as well as many of our colleagues, are using the Milwaukee brace with increasing satisfaction When we are sure that all of the "bugs" are out of the method, we plan to publish the technique in detail

DR ARTHUR STEINDLER, IOWA CITY, IOWA First, a point of definition What is scoliosis? The earmark of scoliosis is the irreversibility of the position of the spine If the spine is no longer subject to voluntary muscle control, there is evidence of beginning structural changes I do not admit the term "physiological scoliosis"

Second, scoliosis is a deformity in which the spine penetrates into the thorax by a process of lateral displacement and rotation It leaves the thorax behind in rotation I have not heard a word about displacement of the thorax The thorax is always displaced on the concave side Correction of the thorax must always be carried out, therefore, by convex-side detorsion

Third, I almost feel like falling on Dr von Lackum's neck, not because he mentioned my name, but because after twenty-five years of my preaching about compensation, he has finally come back to it I started emphasizing compensation and I still take that stand, he started with correction and now comes back to compensation

What is compensation? It is the development of counter curves, so that realignment occurs between occiput and pelvis The case showed by Dr von Lackum, with 100 degrees' deviation of what he called the primary curve, does not show any compensation The curvature of the body was transmitted and continued through the pelvis and lower extremities One of the hips was in abduction and the other in adduction,—the earmarks of decompensation This same principle applies to the anteroposterior curve If you have a round hollow back and both curves are of equal length and angular value, they are compensated On the contrary, if the curve includes the pelvis and extends through the lower extremity, the curve includes the entire length of the body Such a curve is not compensated It is necessary to make a definite decision as to what constitutes compensation I do not see how any misconception or confusion can arise, if the definitions are elaborated on simple mechanical lines

THE ILIOTIBIAL BAND

Its Role in Producing Deformity in Poliomyelitis *

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In 1926, Yount presented an excellent study of the tensor fasciae femoris and indicated its part in producing deformity of the lower extremities. He pointed out a triad of deformities,—hip-flexion and abduction contracture, knee-flexion contracture, and knock-knee. During the twenty-two years following this classical publication, there has been ample material available to make it possible for one to understand better the role of contracted fascia lata in lower-extremity deformities, and the important part it plays in the severe pelvic and trunk deformities so often seen.

The iliotibial band with its allied structures is probably the greatest deforming factor in lower-trunk and lower-extremity involvement following infantile paralysis. It has been said that this is a fact only in those cases which had had no care, or in which treatment had been inadequate during the acute and early convalescent stages. This is not always true. The author has seen these contractures appear and progress, in spite of the best conservative treatment available to the patient. The importance of these structures as a deforming factor has not been sufficiently emphasized since the original work of Yount.

The iliotibial band is the thickened portion of the fascia lata along its lateral aspect. The fascia lata has an extensive origin. It arises as far posteriorly as the coccyx and sacrum, laterally to the crest of the ilium, and anteriorly to Poupart's ligament and the superior ramus of the pubis. It is composed of two layers,—a superficial layer which covers the glutaeus maximus and tensor fasciae femoris, and a second layer deep to these muscles. It gives attachment to most of the fibers of the glutaeus maximus and to all of the fibers of the tensor fasciae femoris. The fibers of the fascia lata then converge to form the iliotibial band on the lateral aspect of the thigh. It is continuous medially with the lateral intermuscular septum, through which it gains attachment to the linea aspera throughout its length. Distally, it gives origin to the short head of the biceps. As it reaches the level of the knee joint, it again spreads out to become attached to all of the lateral prominences just below the knee, including the head of the fibula. It is important to remember that the iliotibial band lies in a plane anterior and lateral to the axis of the hip joint, and in a plane posterior and lateral to the axis of the knee joint.

Involvement of the muscles attached to this band is responsible for the increased tension under which it is placed during the acute and early convalescent stages of poliomyelitis. Spasm in the short head of the biceps and increased tension in the iliotibial band can be easily demonstrated by an attempt to extend the leg on the flexed thigh. Spasm in the glutaeus maximus can be easily demonstrated by flexing the extended leg on the trunk. If the increased tension in the iliotibial band during the acute or early convalescent stage is not released by adequate conservative care, this tension becomes a progressive contracture.

Treatment indicated for the patient in the acute stage should be continued until the joints of the hip and the knee can be passively carried through their full range of motion in all directions without force, and without pain or discomfort to the patient. When this has been accomplished, the full length of the iliotibial band will have been preserved, and deformities due to its contracture will be less likely to occur.

* Presented at the Instructional Courses of the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 1948.

LOWER-EXTREMITY DEFORMITIES

A contracture of the iliotibial band on one side may contribute directly or indirectly to the development of the following deformities

1 *Flexion and Abduction Contractures of the Hip*

The band occupies a plane lateral and anterior to that of the hip joint The pelvis is the fixed point from which the femur is flexed and abducted

2 *Contracture of the Thigh in External Rotation*

For comfort, patients with this deformity maintain the involved extremity in an attitude of flexion, abduction, and external rotation of the hip, flexion of the knee, and equinus and varus of the foot The external rotators of the hip undergo adaptive shortening to conform to this position

3 *Genu Valgum*

The tibia will be abducted and may be flexed on the femur The band continuous with the lateral intermuscular septum gains attachment to the entire shaft of the femur along the linea aspera The lateral femoral condyle does not project as far distally as the medial condyle in structural knock-knee deformity It is entirely possible that these bone changes are due to the greater resistance offered by the more dense lateral septum As the genu valgum increases, the band is placed in a more advantageous position to further increase the deformity The contracted band exerts a force on the lateral aspect of the joint, similar to that which the taut string exerts on the concavity of an archer's bow

FIG 1 FIG 2

Fig 1 Varus deformity of the foot caused by the application of a brace to an extremity where tibial torsion was present

Fig 2 Functional varus was corrected when thigh portion of the brace had been externally rotated

Although numerous factors are responsible for inequality of limb length, there is reason to believe that the dense band attached to the femur throughout its length can contribute to the over-all shortening of this long bone The band crosses both femoral epiphyses and the upper tibial epiphysis In a growing child, the band tends to become relatively shorter as the femur becomes longer A tremendous discrepancy may be present in the length of extremities with a short band on one side If some epiphyseal arrests do not appear to be retarding growth to the extent that is expected, a tight iliotibial band on the opposite side may be a contributing cause

4 *Knee-Flexion Deformity and External Torsion of the Tibia*

As the deformity increases, the knee may become contracted in flexion, since the band occupies a plane posterior to that of the knee joint With the knee in a flexed position, the tibia and fibula will rotate externally and the tibial condyles may begin to subluxate on the femur The fibular head can often be palpated in the popliteal space This is particularly true if the short head of the biceps is strong

5 *Varus Deformity of the Foot*

There are various causes of varus deformity of the foot One of the most common is an attempt to fit a long brace to an extremity in which external torsion of the tibia is evident The varus deformity develops in the presence of this torsion, because the axes of the knee and ankle joints do not occupy the same horizontal plane, whereas the axes of these joints in an ordinary walking brace are in the same horizontal plane When such a brace is placed on an extremity with external torsion of the tibia, and the thigh portion is prevented from externally rotating by a pelvic band, the foot must turn into the varus position to be in line with the knee joint (Fig 1)

If the thigh portion of the brace is allowed to rotate externally on the thigh, the functional varus deformity will disappear, as the foot can assume its normal relationship to the ankle (Fig 2) The deformity, at first, is purely functional, due to the brace, but later it undergoes typical structural changes, requiring surgical intervention

DEFORMITIES OF THE PELVIS AND TRUNK

1 *Pelvic Obliquity*

The thigh is flexed and abducted in relationship to the vertical axis of the body only when the pelvis is level or is at a right angle to the vertical axis of the trunk When the extremity on the side of the flexion and abduction contracture is forced into a weight-bearing position (parallel to the vertical axis of the body), the pelvis is forced into an oblique position The obliquity is now the existing deformity, although it has been caused by contractures below the iliac crest

A lumbosacral scoliosis must necessarily develop simultaneously with the pelvic obliquity If the pelvis is held in an oblique position by contractures below the crest, the lateral trunk muscles of the opposite side will contract to conform to the oblique position of the pelvis Structural changes in the lumbar vertebrae will follow, producing a structural scoliosis

2 *Exaggerated Lumbar Lordosis*

When flexion contracture is present on both sides, the entire pelvis is tilted forward, producing exaggerated lumbar lordosis

TREATMENT

A contracture, or shortening, of the iliotibial band cannot be corrected with conservative stretching and manipulation by the physical therapist, neither can it be overcome by the application of a series of plaster casts by the orthopaedic surgeon Surgical intervention is indicated, regardless of the age of the patient or the duration of illness It is impossible to lock the pelvis securely enough to allow a corrective force of any consequence to be exerted on the contracture The anterior and lateral abdominal muscles on the side of the contracture are the muscles which will undergo stretching by these conservative measures The pelvis will simply be forced into an oblique and hyperextended position

A Soutter fasciotomy, the long-accepted operation for the correction of these contractures, is a procedure to be condemned, as numerous recurrences have followed this procedure It is an ill-advised operation for the following reasons These deformities are caused, not by contractures of the normal muscle tissues, but rather by shortening or contracture of the intermuscular septa and enveloping fascia This fact can easily be demonstrated by dividing the contracted fascia covering the normal muscle tissue, even after the cut edges of the fascia retract an inch or more, the normal underlying muscle tissue can be picked up with tissue forceps and found to be in a relaxed condition Muscles that are partially involved can become shortened, due to contracture of the involved fibrosed muscle tissue scattered throughout the normal muscle fibers, and in this manner can contribute to the severity of the deformity This explains, in part at least, why these

Fig 3

Fig 4

Fig 5

Fig 3 The extremity on the side which has been operated upon is held in flexion and abduction Sufficient traction to level the pelvis is applied through the Kirschner wire incorporated in the cast on the side of the unaffected extremity

Fig 4 Fixed skeletal traction The spine is flat and the pelvis is level The spica on the side of the unaffected extremity has been completed, locking this segment in as a unit

Fig 5 Fixed skeletal traction plus plaster wedging A double spica is completed after the extremity on the affected side has been adducted and extended until considerable resistance is felt Additional correction is easily obtained by wedging the involved extremity further into extension and adduction at the hip

deformities occur in flail extremities and why, in the unilateral cases, these deformities involve the extremity with the greater weakness.

The short fascia and fibrosed muscle tissue extend from the crest of the ilium distally to the head of the fibula. The important thing to remember is that this short fibrous mass can produce as much deformity distally about the knee as it can proximally about the hip. The offending structures must be attacked proximally as well as distally. A fasciotomy for the hip of the Ober type and a Yount fasciotomy for the iliotibial band and lateral intermuscular septum are the operative procedures of choice.

Ober's fasciotomy consists in dividing the fascia and the intervening fibrosed and fascial bands over the sartorius, rectus femoris, and tensor fasciae femoris, as far back as the greater trochanter. Injury to the lateral femoral cutaneous nerve should be avoided.

The author's conception of a Yount fasciotomy is the removal of a block of the iliotibial band (2 to 3 centimeters), division of the lateral intermuscular septum down to the femur, and section of the fascia lata covering the vastus lateralis. This is done about four inches (10 centimeters) above the knee joint.

One should not try to correct completely these contractures on the operating table. In cases with bilateral deformity, the patient should be placed postoperatively on a hyperextended Bradford frame with both lower extremities enclosed in toe-to-groin casts which are attached by a crossbar to prevent external rotation. The deformities have usually been corrected by the time the sutures can be removed. For the postoperative correction of the more severe deformities, wedging in a double spica may be necessary.

For postoperative correction in cases with unilateral deformity, it is first necessary to pass a Kirschner wire through the femur on the unaffected side, just above the condyle. Toe-to-groin casts are applied to both lower extremities, a Kirschner wire being incorporated on the unaffected side. The patient is then placed on a fracture table, the thigh on the side operated upon is held in flexion and abduction. Sufficient traction is exerted on the unaffected side, through the wire incorporated in the cast, to bring the pelvis to a right angle with the vertical axis of the trunk (Fig. 3).

With traction maintained, the body portion of the spica on the unaffected side is finished and allowed to set. The patient now has a single spica, incorporating the trunk, pelvis, and femur on this side. The pelvis is level and the lumbar spine is flat (Fig. 4).

The extremity on the affected side, which has been maintained in flexion and abduction and has not been incorporated in the spica, is internally rotated, extended, and adducted until considerable resistance can be felt. The double spica is now completed by tying this extremity to the single spica already applied to the other side. Additional correction is easily obtained by wedging the extremity further into increased extension and adduction every three to five days (Fig. 5).

The advantages of fixed skeletal traction plus plaster wedging over well-leg traction become apparent when these deformities are more closely analyzed. There is an element of flexion as well as of abduction in these contractures. The flexion element is not apparent as long as the extremity is in abduction.

When the abducted extremity has been adducted toward the mid-line, the flexion contracture becomes evident. The pelvis is tilted downward and forward, the lumbar lordosis is exaggerated. This is the abnormal position of the spine and pelvis when the cast is applied for well-leg traction. This traction will correct the abduction by increasing the distance from the trochanter to the anterior superior spine, with the pelvis rotating on the femoral head. Additional traction, however, will tend to force the lumbar spine into further lordosis, due to the undisturbed flexion contracture.

With fixed skeletal traction, the surgeon begins the correction of abduction and flexion contractures simultaneously, the pelvis is level and the lumbar spine is flat. The trunk, pelvis, and the normal lower extremity are locked and held in their normal positions by the Kirschner wire incorporated in the plaster on the unaffected side.

In long-standing deformities, when the other muscles mentioned are secondarily contracted and contribute to the severity of a tight iliotibial band, a Soutter fasciotomy may rarely be necessary, in addition to section of the iliotibial band The iliotibial band should always be sectioned, even though a Soutter fasciotomy is indicated No correction is attempted on the operating table, and the final correction is always obtained by fixed skeletal traction plus plaster wedgings, as outlined previously

The surgeon who attempts to correct and to fuse a curve in the lumbar spine, when the pelvis is part of that curve, invites disaster if, before doing the fusion, he does not release all contractures below the crest of the ilium which contribute to the deformity In all knock-knee deformities requiring osteotomy in the supracondylar region, section of the iliotibial band and lateral intermuscular septum should be done at the same time, if the contracture contributes to the knock-knee deformity

Every severe and disabling deformity following poliomyelitis has an almost insignificant beginning It is important to be thorough in examination, to recognize these early functional deviations, and to correct them before fixed deformities of paramount importance develop

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TREPHINE BIOPSY OF BONE WITH SPECIAL REFERENCE TO THE LUMBAR VERTEBRAL BODIES *

BY ROBERT S SIFFERT, M D, AND ALVIN M ARKIN, M D, NEW YORK, N Y

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Aspiration biopsy of bone presents the same advantages in differential diagnosis as does aspiration biopsy of soft tissues Bone biopsy is usually much more difficult, however, because of the technical problem involved in obtaining an adequate piece of material from what is frequently a relatively inaccessible site In the process of boring through bone, aspirating the specimen, and expressing it by the use of the ordinary needle, there is usually marked distortion of the tissue architecture This distortion adds to the already difficult problem of pathological interpretation

Most vertebral-body lesions can be diagnosed adequately by a correlation of clinical, laboratory, and roentgenographic findings However, the problem of differential diagnosis frequently arises, and, because of the inaccessibility of the vertebral body surgically, the clinician must often be satisfied with a presumptive diagnosis

* Read before the Orthopaedic Section, New York Academy of Medicine, April 16, 1948

† Robert K Lippmann, M.D, Director

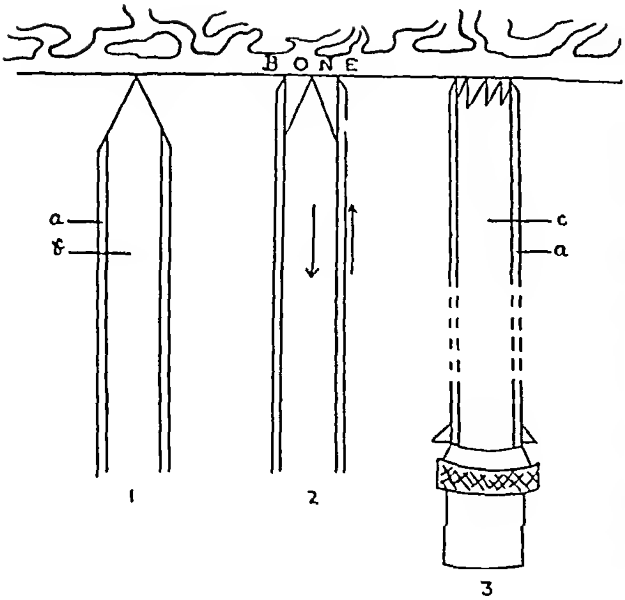

Fig. 1

Fig. 2

Fig. 1. The outer needle (*a*) with stylet (*b*) is inserted down to bone (*1*). The needle is advanced over the stylet to the bone, and the stylet is withdrawn (*2*). The inner saw-toothed biopsy needle (*c*), with hub adapted to fit a quarter-inch hand drill chuck, is inserted into the first needle (*3*). The hub has a knurled handle for finger rotation in the case of soft or cystic lesions.

Fig. 2. A case in which chordoma was shown on biopsy examination. The needle is correctly positioned against the body from which biopsy material is to be obtained. Note the landmarks. The lower tip of the spinous process of the body from which biopsy material is to be obtained corresponds to the level of the transverse process of the body below.

Kirschner, Christiansen, and Ellis used a motor-driven drill with a squared-off needle to obtain biopsy material from soft tissue and bone. Turkel and Bethell introduced an inner needle with a trephine tip, which was rotated by hand within an outer protecting needle, principally for soft-tissue biopsy.

Although accurate diagnosis can frequently be made with tissue obtained from the vertebral body by means of a routine aspirating needle, the tissue usually represents distorted bone fragments and marrow contents. Because of the difficulty of pathological interpretation of these small bits of distorted tissue, a needle was devised which employs the principles of the Turkel needle.

There are several features that make this new needle an excellent instrument for bone biopsy. The beveled tip of the stylet is short and spear-shaped, to minimize the amount of soft tissue obtained before contact with the bone is actually made with the inner biopsy needle (Fig. 1). The inner needle is carefully tooled and has ripsaw teeth, beveled on the leading edge, and projects 3.5 centimeters beyond the outer needle when fully inserted. The inner bore of the needle is straight, to permit easy advancement of the core up the needle. Wedge-shaped tips and inner-threaded tips were tried, but they obstructed the advancement of the core by wedging of bone in the tip of the needle. A most important feature is the use of a hand drill to accomplish rapid, steady, controllable rotation of the needle; this results in a uniform core of bone with little distortion of the architecture within the core. The hub of the needle is made to fit into a quarter-inch hand drill, but also contains a knurled handle to permit hand rotation for soft or cystic lesions.

TECHNIQUE

The technique of insertion of the needle is similar to that employed in paravertebral block of the lumbar sympathetic chain, with the exception that the angle made with the vertebral body is slightly less acute, to prevent the needle slipping off the body anteriorly, and to permit obtaining the maximum amount of tissue from the center of the body. The biopsy is performed under local or light general anaesthesia with roentgenographic control

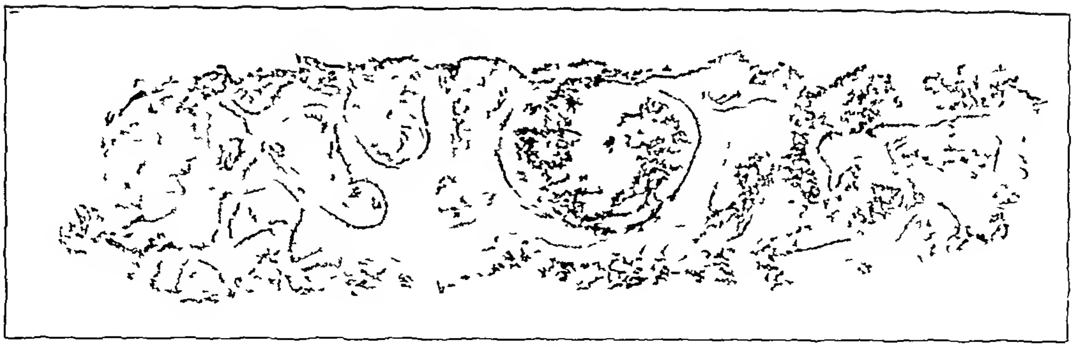

Fig 3-A

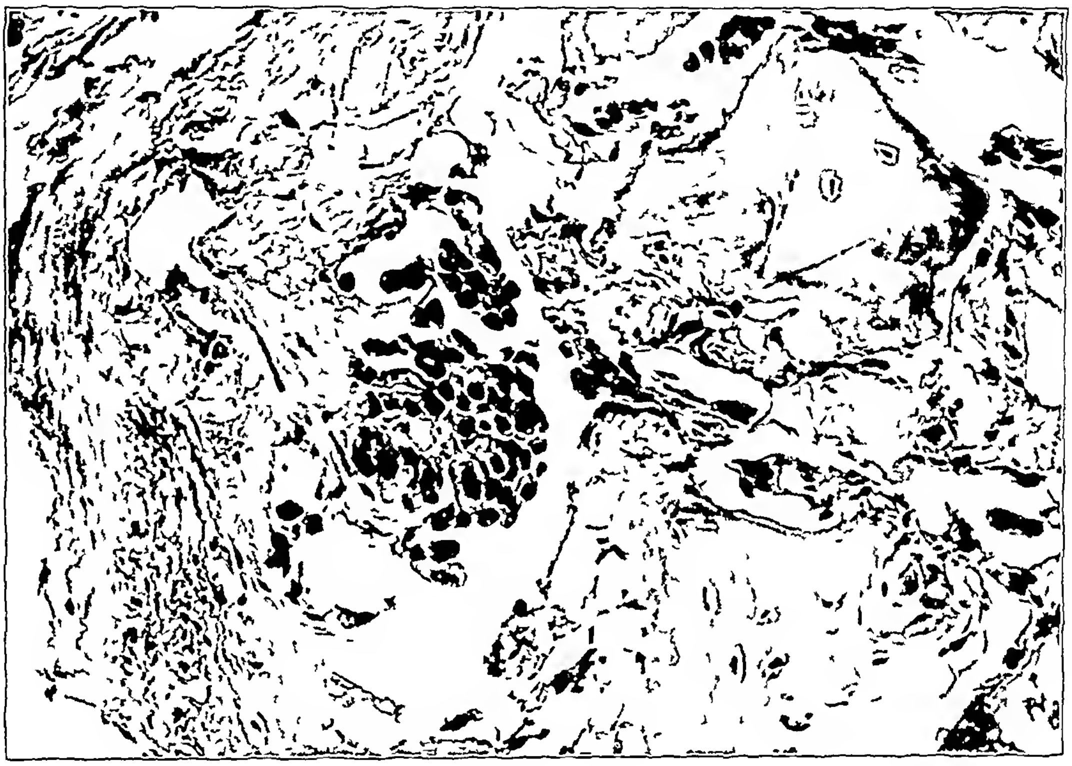

Fig 3-B

Photomicrographs showing tissue obtained by the needle Fig 3-A shows a core of bone from a vertebral body under low-power magnification (X 21), demonstrating undistorted bony architecture In Fig 3-B a section of metastatic adenocarcinoma from the vertebral body, under high-power magnification (X 330), demonstrates undistorted details of tumor and bone

A well-centered postero-anterior roentgenogram is studied in advance because of alterations in landmarks, due to anatomical variations or vertebral collapse In general, the lower tip of the spinous process of the body to be biopsied will correspond to the level of the transverse process of the body below (Fig 2) The path of the needle and the paravertebral area are well infiltrated with novocain, a long, fine-gauge needle being used, with the patient in the prone position A scalpel-point incision is made at the level chosen, about three and one-half fingerbreadths (6 to 7 centimeters) lateral to the mid-line The first needle, with stylet, is inserted downward and inward at an angle of 45 degrees with the surface of the skin, until the transverse process is encountered The needle is withdrawn slightly and the angle is changed, so that it glances off the superior border of the transverse process as it is advanced down to the vertebral body A roentgenogram is taken and, if the needle is directed correctly, as shown in Figure 2, the stylet is removed and the inner cutting-edge needle on a hand drill is inserted A core is removed by rotating the drill at the desired speed, with controllable directional pressure, depending

upon the consistency of the bone. The size of the core can be regulated by calibrations on the inner needle. When the biopsy has been completed, several turns of the needle are accomplished without advancement, to assure cutting off the core at its base. The inner needle is removed with the core inside, and the core is expressed with a stylet (Figs. 3-A and 3-B). If the tissue is of solid consistency, it remains within the needle and suction is unnecessary. If it is soft or cystic, hand rotation can be employed, and syringe suction is maintained as the inner needle is withdrawn.

The technique of trephine biopsy of bones other than the vertebral bodies is identical to that just described.

DISCUSSION

This technique of trephine biopsy presents several advantages. After removal of the inner needle containing the biopsy core, a long needle can be inserted into the first needle, which is held in place, and any fluid material in the lesion can be aspirated for smear, guinea-pig inoculation, culture, or other laboratory procedure. The presence of the outer needle precludes soft-tissue injury due to rotation of the inner biopsy needle. In addition, by moving the outer needle slightly along the surface of the bone, many cores can be obtained from neighboring areas without reinsertion of the needle.

By approaching the vertebral body less acutely than in the technique of lumbar paravertebral block, the needle strikes the posterolateral aspect of the vertebral body at such an angle that there is very little likelihood of its slipping anteriorly. Nerve-root puncture occurs infrequently, and causes signs of root irritation only momentarily. These disappear as soon as the direction of the needle has been changed.

In view of the frequent distortion of the anatomical landmarks, it is more accurate and simpler, in approaching the vertebral body, to employ the relationship of spinous process to transverse process to vertebral body on the roentgenogram than to use a fixed-angle guide apparatus for all cases, as described by Valls, Ottolenghi, and Schajowicz.

In aspiration biopsy of bones other than the vertebral bodies, this needle is equally useful. Little difficulty was encountered in approaches to such relatively inaccessible areas as the supra-acetabular and the infra-acetabular areas of the pelvis and ischium. Penetration of a thick cortex has been accomplished by the use of the hand drill, and it has never been found necessary to use a motor drill. Most superficial bone biopsies, where roentgenographic control is unnecessary, can be performed under local anaesthesia in the office or at the bedside.

SUMMARY

The relative inaccessibility of the vertebral body for surgical biopsy makes trephine biopsy valuable in this region. By use of the needle described, excellent, adequate undistorted cores of tissue may be obtained, to aid in the differential diagnosis of many lesions.

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SURVIVAL AND GROWTH OF AN EPIPHYSIS AFTER REMOVAL AND REPLACEMENT

BY J ALBERT KEY, M D , ST LOUIS, MISSOURI

From the Department of Surgery, Washington University School of Medicine, St Louis

In 1946, the author [2] reported the case of a boy, eleven years of age, who had suffered a dislocation of the elbow with a fracture through the neck of the radius and displacement of the head of the radius backward into the elbow joint The dislocation was reduced by the family physician, and the patient was then brought to St Louis for treatment of the fracture-dislocation of the head of the radius

He was operated upon about forty-eight hours after the injury, and the head of the radius, which included the epiphyseal line and a bit of the neck, was found completely free in the posterior portion of the

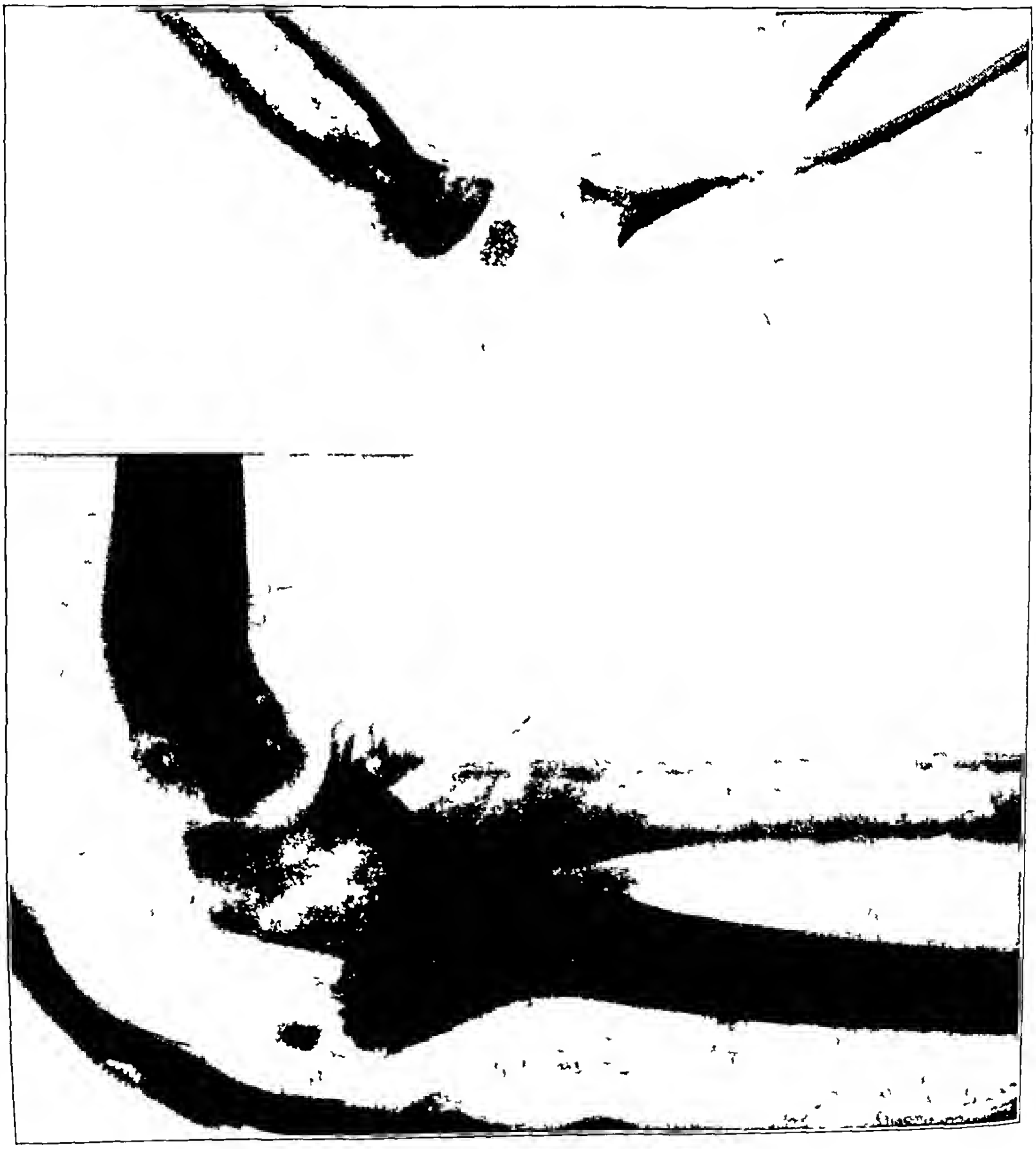

FIG 1

Dislocation of the head of the radius Preoperative and postoperative views
(Reproduced from article by J A Key, which appeared in *The Journal*, 28 148, Jan 1946)

FIG 2

Lateral and anteroposterior views of elbow, about thirteen months after operation (Reproduced from article by J A Key, which appeared in *The Journal*, 28 148, Jan 1946)

elbow joint It was lifted out with forceps, placed in a folded towel, and laid upon the instrument table while a bed was prepared for it It was then replaced on the neck and the elbow was flexed to 90 degrees, the capsule was sutured around the head, the wound was closed, and the extremity was immobilized in a plaster cast, care being taken to disturb the position of the parts as little as possible during the application of the cast The cast was removed eight weeks after the operation, and the boy was advised to begin to use the arm, but to avoid strain for a few weeks

He returned thirteen months after the operation for a check-up, it was found that the movements of the elbow were almost normal, there being about 5 degrees of limitation of extension The roentgenograms at that time (Fig 2) showed the head of the radius united and in satisfactory position It was the author's opinion that the head of the radius and the epiphyseal line were living

The previous report has been criticized by some who think that insufficient time had elapsed for an end-result report, and that the head of the radius looks dead in the reproduction of the roentgenograms (Fig 2) Fortunately this boy has recently returned to St Louis, by request, for another examination

He is now fifteen years old, and at the time of the last examination a little over four years had elapsed since the operation He has grown rapidly, and is now five feet, eleven and one-half inches tall The boy plays basketball and baseball on his high-school teams, and states that at no time has he noted weakness, pain, or disability in the elbow He states that this is his throwing arm and that he is able to throw a baseball as well as other boys on his team

On physical examination, flexion and extension of the elbow and rotation of the forearm were normal when compared with the uninvolved left upper extremity There was no evidence of shortening of the radius or of deformity of the elbow or wrist The only abnormality noted was slight soft crepitus on palpation over the head of the radius, while the forearm was being rotated Roentgenograms (Fig 3) show the head of the radius living and united to the neck with slight angulation The epiphyseal line appears closed This boy now has an approximately normal right upper extremity

The author believes that this report affords sufficient evidence to warrant reiteration

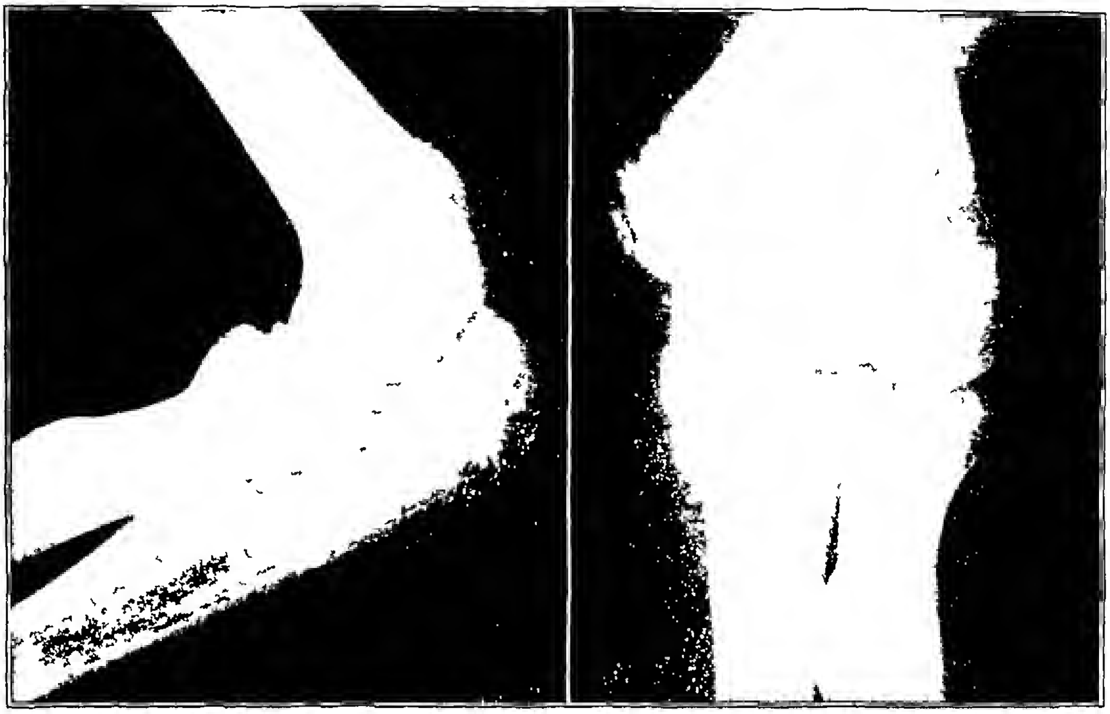

FIG 3

Roentgenograms of the elbow of a boy, fifteen years of age, in whom the head of the radius had been completely removed and replaced at the age of eleven, four years and one month before The epiphysis has survived and grown at the normal rate It is possible that some of the head may have died and been replaced (These x-rays have been reversed)

of the statement that, in children, epiphyses should be replaced if possible, because they may survive and the bone may grow normally, even though the epiphysis has been completely separated and is without blood supply[1] In these days of bone banks, this case is of interest because it brings up the perennial question of how much of a bone graft lives, it may constitute some evidence on behalf of the autogenous graft

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ACUTE ANTERIOR DISLOCATION OF THE SHOULDER*

BY TOUFICK NICOLA, M.D., MONTCLAIR, NEW JERSEY

Six years ago, the author reported to this organization on the role of the articular capsule in anterior dislocation of the shoulder. Included in this report were observations based on the pathological findings in five cases of acute anterior dislocation. Since that time, the author has operated upon twenty-two more acute dislocations of the shoulder and has found that the location and extent of the pathological lesion vary in different cases, depending upon the producing force.

A force of hyperabduction will tear the capsule from the neck of the humerus and, if severe enough, will tear part or all of the subscapularis tendon from its attachment to the neck of the humerus (Figs. 1 to 8). If a force of impaction is added while the arm is going into abduction, the capsule and the labrum will tear away from their attachment to the neck of the scapula. The capsule will also tear, in a longitudinal direction, as the head becomes dislocated (Figs. 9 and 10).

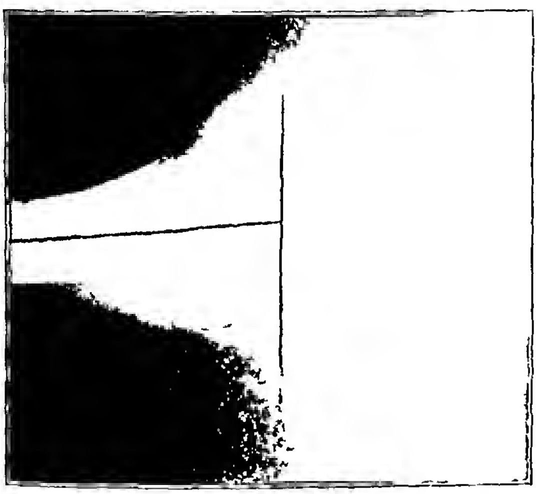

FIG. 1

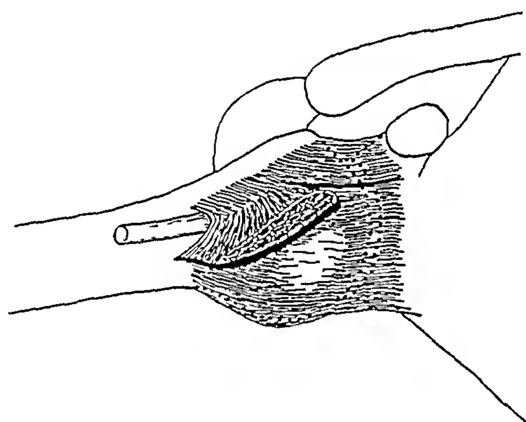

FIG. 2

Fig. 1. Roentgenogram of shoulder in 85 degrees of abduction.
Fig. 2. Position of capsule when shoulder is in 85 degrees of abduction.

FIG. 3

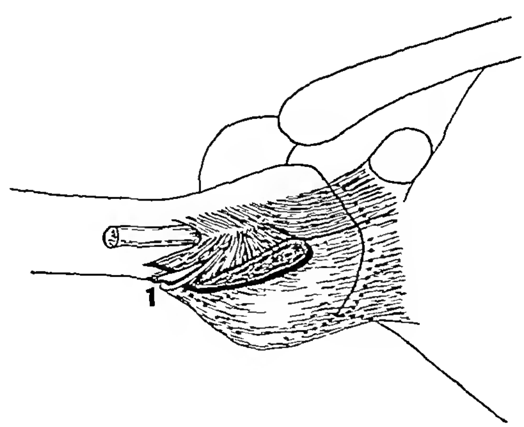

FIG. 4

Fig. 3. Roentgenogram of shoulder in 105 degrees of abduction.
Fig. 4. Capsule (*1*) begins to tear away from neck of humerus when shoulder is in 105 degrees of abduction.

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 29, 1948.

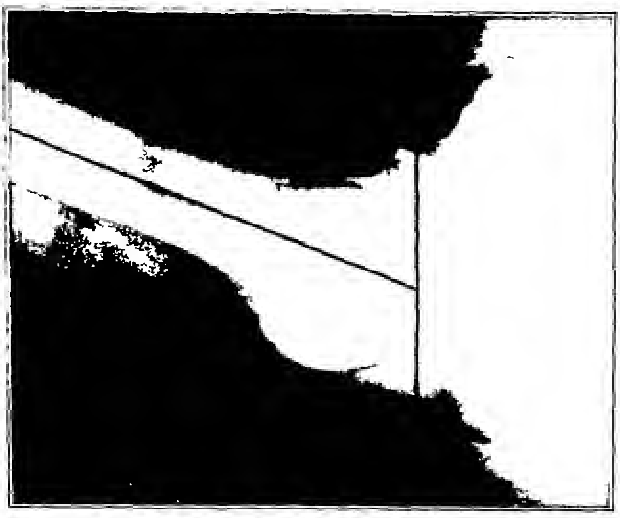

Fig 5

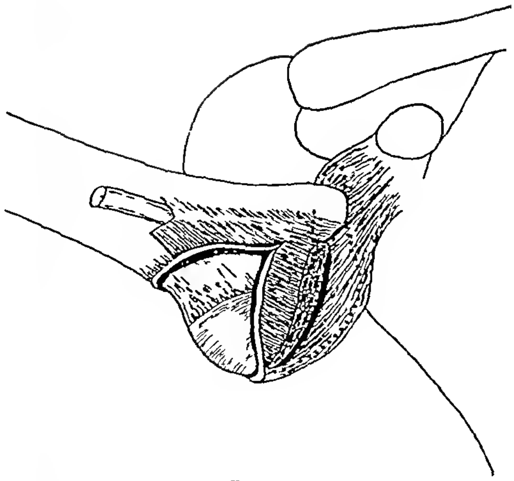

Fig 6

Fig 5 Roentgenogram of shoulder in 115 de-grees of abduction

Fig 6 Capsule and part of subscapularis have torn away from neck of humerus when shoulder reaches 115 degrees of abduction

Fig 7

Fig 7 Hyperabduction tears capsule and sub-scapularis tendon from neck of humerus

Fig 8 Capsule and subscapularis tendon torn away from neck of humerus and sucked into joint, covering glenoid cavity (*1* indicates anterior capsule covering glenoid cavity)

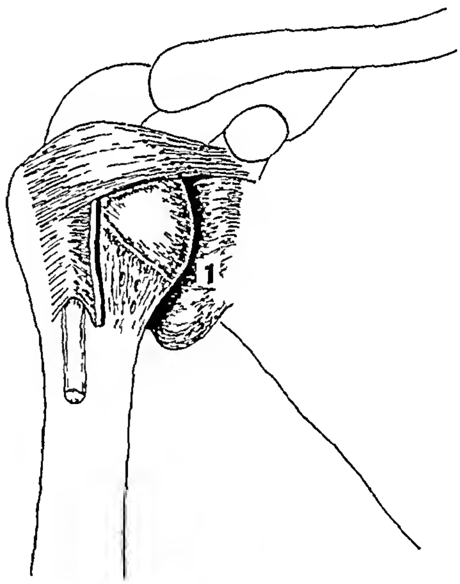

Fig 8

Fig 9

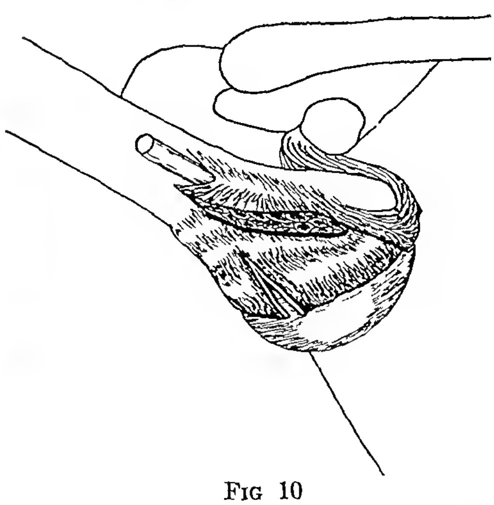

Fig 10

Fig 9 Force of abduction and impaction produced by fall on elbow

Fig 10 Capsule torn away from rim of glenoid cavity by force of abduction and impaction

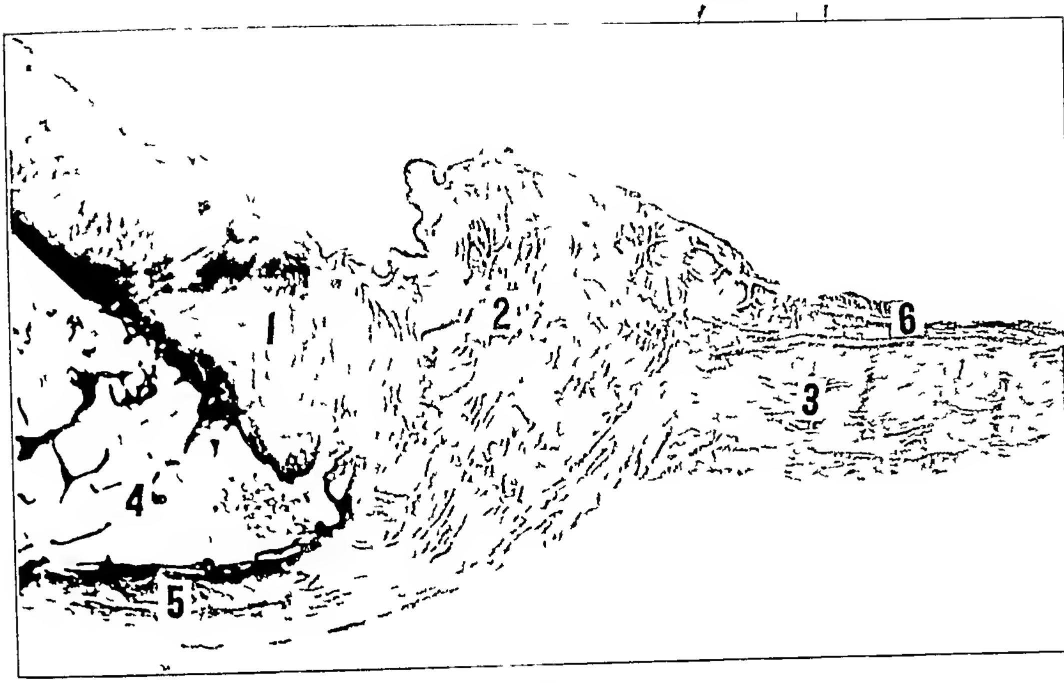

Fig. 11

Section of glenoid cavity, taken at anterior inferior aspect (about four o'clock).
1, Cartilage covering glenoid cavity; *2*, labrum; *3* and *5*, capsule; *4*, bone of glenoid; and *6*, synovial membrane.

There is still a misconception about the method of attachment of the capsule and labrum to the scapula. Some surgeons think that the capsule and labrum are attached to the rim of the glenoid cavity and that, when they are torn away from this attachment, they do not become reattached. Therefore, we have recurrent dislocation of the shoulder. However, the observations of the author, made in 1941, and those of Fahey and DiCosola, in 1947, show that the capsule and labrum are attached primarily to the periosteum which covers the neck of the scapula (Fig. 11).

The report presented here is based on a study of twenty-seven consecutive cases of acute anterior dislocation of the shoulder.

Case 1. A school teacher, thirty-three years old, had a stiff shoulder which was manipulated under anaesthesia in order to increase motion. After manipulation, the hand was attached to the head of the bed for five days, during which time the patient complained of severe pain in the shoulder region. When the hand was released, the patient could not bring her arm down to her side. Roentgenograms showed anterior dislocation of the shoulder. After a closed reduction had proved unsuccessful, the shoulder was explored. The anterior capsule and the subscapularis tendon had been torn away from their attachments to the neck of the humerus and were covering the glenoid cavity. After the capsule and the subscapularis tendon had been lifted, it was possible to replace the head in the glenoid cavity. The capsule and the subscapularis tendon were then reattached and, at the end of two weeks, the patient was instructed to exercise her shoulder to prevent stiffness. Seven weeks later the shoulder became redislocated. The patient refused further operation.

Case 2. A farmer, forty-eight years old, fell between two trucks and his right arm was forced over his head. Roentgenograms showed anterior dislocation of the shoulder. Exploration before reduction disclosed that the head of the humerus was lying under the coracoid process, the capsule and subscapularis had been torn away from the neck of the humerus and were covering the glenoid cavity. The head of the humerus was replaced under the acromion by the use of downward traction and by forcing the arm from the side of the chest wall. It redislocated very easily. It was necessary to lift out the capsule and subscapularis tendon before the head of the humerus could be reduced satisfactorily. No attempt was made to repair the defect, but the shoulder was immobilized for eight weeks in an apparatus which prevented abduction and external rotation. At the end of five years the dislocation had not recurred.

Case 3. A housewife, aged thirty-nine, was standing on a stool to hang curtains. The stool slipped, she grasped the curtains, and felt something give in her right shoulder. Roentgenograms showed anterior dislocation of the right shoulder. On exploration, the anterior portion of the capsule and the lower half of the sub-

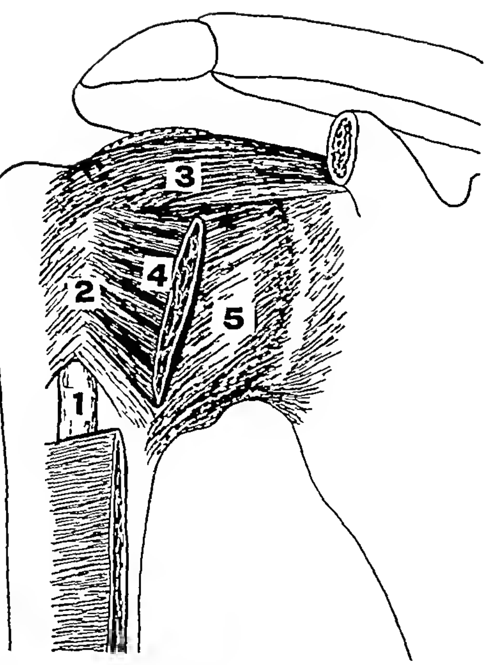

Fig 12-A

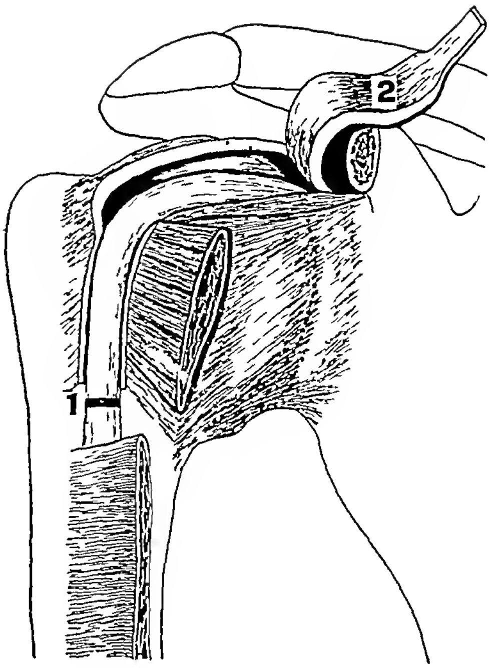

Fig 12-B

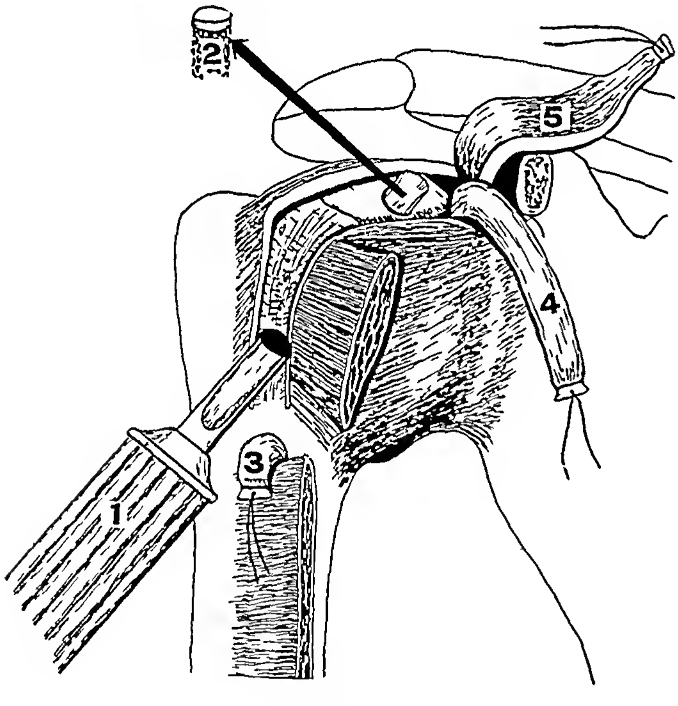

Fig 12-C

Fig 12-A Anterior aspect of shoulder joint

1, Long head of biceps
2, Transverse humeral ligament
3, Coracohumeral ligament
4, Subscapularis tendon
5, Anterior portion of capsule

Fig 12-B *1*, Point of division of long head of biceps
2, Transverse humeral and coracohumeral ligaments, reflected up to base of coracoid

Fig 12-C *1*, Gouge in position through head of humerus
2, Plug from head of humerus
3, Distal portion of long head of biceps
4, Proximal portion of long head of biceps

scapularis tendon were found to have been torn away from the neck of the humerus No attempt was made to repair the capsule or the tendon, but the dislocation of the shoulder was reduced by traction and adduction, with the fist high in the axilla Then the shoulder was immobilized for seven weeks To date, after three and a half years, there has been no recurrence

Case 4 A woman, thirty-eight years old, had a stiff shoulder, which was manipulated under anaesthesia and direct vision The abduction manipulation tore the capsule away from the neck of the humerus in a longitudinal direction When abduction was continued, the head of the humerus became dislocated The head was replaced by downward traction and adduction, with the fist high in the axilla The shoulder was immobilized for eight weeks At the end of a year there had been no recurrence, but the motions in the shoulder were still restricted about one-half in all directions

Case 5 A basketball player, while shooting a ball into a basket, had his arm pushed up farther He felt something tear and give way in his left shoulder Roentgenograms showed an anterior dislocation Exploration disclosed that the capsule and part of the subscapularis tendon had been torn away from the neck of the humerus No attempt was made to repair the capsule or the subscapularis tendon The patient resumed athletics at the end of three weeks, and one month later this shoulder became redislocated when he was trying for a basket At reoperation, the capsule was found to be loose, although healed and intact The labrum had

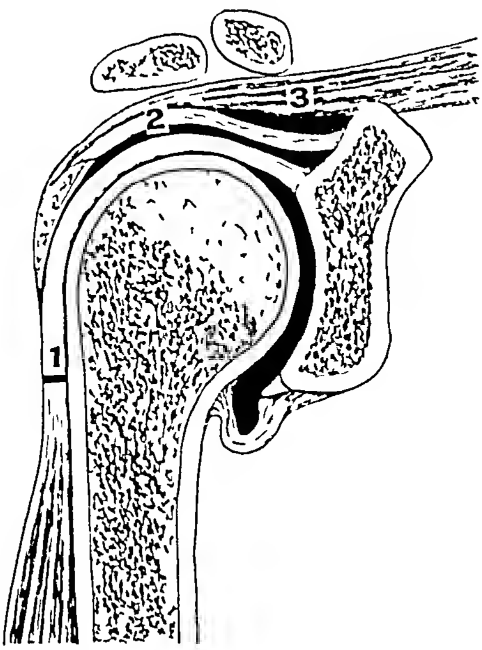

FIG 12-D

Frontal section of shoulder
1, Long head of biceps
2, Coracohumeral ligament
3, Supraspinatus muscle

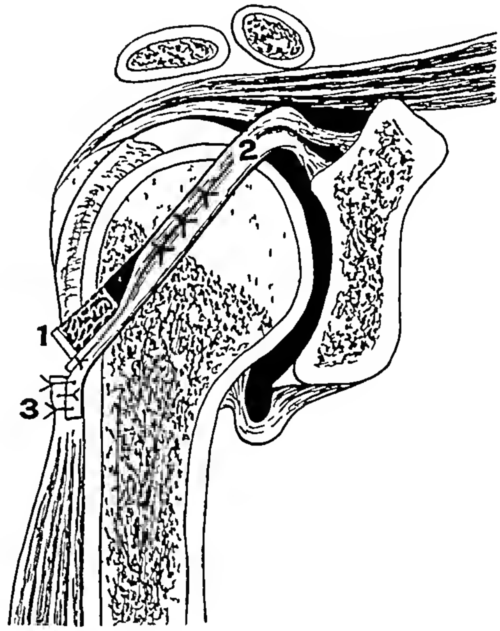

FIG 12-E

Frontal section of shoulder
1, Plug of bone in position
2, Coracohumeral ligament and long head of biceps have been passed through head of humerus
3, Long head of biceps has been sewed together

torn loose from the rim of the glenoid, but the capsule was still attached to the neck of the scapula This case was treated by anterior capsulorrhaphy and by passing the long head of the biceps and the coracohumeral ligament through the head of the humerus (Figs 12-A to 12-E) No recurrence has been reported for two years

CASE 6 A truck driver was thrown from his truck and landed on his left elbow Roentgenograms of the left shoulder showed a fracture of the greater tuberosity and dislocation of the head of the humerus The elbow was lacerated Exploration revealed that the capsule and labrum had torn away from the rim of the glenoid The glenoid was not fractured The head was replaced by downward traction and adduction, with the fist in the axilla No attempt was made to suture the capsule or to reattach the greater tuberosity A

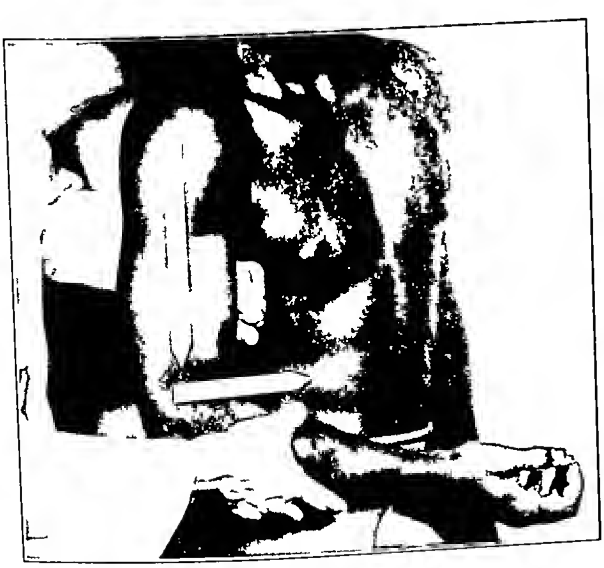

FIG 13-A

FIG 13-B

Fig 13-A Shoulder has been reduced by traction and adduction, with fist high in the axilla
Fig 13-B Showing apparatus which prevents redislocation by restricting abduction and external rotation

TABLE I

SUMMARY OF FINDINGS IN TWENTY-SEVEN CASES

Case No	Age	Occupation	Causative Force	Pathological Findings	Immobilization (*Weeks*)	Results	Remarks
1	34	School teacher	Hyperabduction	Capsule torn from humerus	2	Redislocation	Refused reoperation
2	47	Farmer	Hyperabduction	Capsule torn from humerus	8	Satisfactory	
3	39	Housewife	Hyperabduction	Capsule torn from humerus	7	Satisfactory	
4	38	Housewife	Hyperabduction	Capsule torn from humerus	8	Satisfactory	
5	17	Playing basketball	Hyperabduction	Capsule torn from humerus	3	Redislocation	
6	29	Truck driver	Abduction plus impaction	Capsule torn from scapula	8	Satisfactory	
7	17	Playing basketball	Abduction plus impaction	Capsule torn from scapula	8	Satisfactory	
8	16	Playing football	Uncertain	Capsule torn from scapula	8	Satisfactory	
9	19	Playing football	Uncertain	Capsule torn from scapula	8	Redislocation	Reoperation
10	17	Playing hockey	Uncertain	Capsule torn from scapula	8	Satisfactory	
11	16	Playing football	Uncertain	Capsule torn from scapula	8	Satisfactory	
12	18	Playing football	Uncertain	Capsule torn from scapula	8	Satisfactory	
13	19	Playing football	Uncertain	Capsule torn from scapula	7	Redislocation	Reoperation
14	18	Playing football	Uncertain	Capsule torn from scapula	8	Satisfactory	
15	18	Playing football	Uncertain	Capsule torn from scapula	8	Satisfactory	
16	15	Playing basketball	Uncertain	Capsule torn from scapula	6	Redislocation	Refused reoperation
17	17	Playing basketball	Uncertain	Capsule torn from scapula	8	Satisfactory	
18	17	Playing football	Uncertain	Capsule torn from scapula	8	Satisfactory	
19	15	Playing basketball	Uncertain	Capsule torn from scapula	8	Satisfactory	
20	19	Playing football	Uncertain	Capsule torn from scapula	8	Satisfactory	
21	19	Playing football	Uncertain	Capsule torn from scapula	8	Satisfactory	
22	17	Playing football	Uncertain	Capsule torn from scapula	8	Satisfactory	
23	16	Playing football	Uncertain	Capsule torn from scapula	8	Satisfactory	
24	18	Playing football	Uncertain	Capsule torn from scapula	8	Satisfactory	
25	17	Playing football	Uncertain	Capsule torn from scapula	8	Satisfactory	
26	17	Playing football	Uncertain	Capsule torn from scapula	8	Satisfactory	
27	19	Playing football	Uncertain	Capsule torn from scapula	8	Satisfactory	

special apparatus was applied to restrict abduction and external rotation (Fig. 13-B). There has been no recurrence for three years.

CASE 7. A basketball player fell on his right elbow and dislocated his right shoulder. Exploration showed that the capsule and the labrum had been torn from the rim and neck of the scapula. No repairs were made. The upper extremity was immobilized for eight weeks. No recurrence has been reported over a period of three years.

In the next twenty cases, all high-school students ranging in age from fifteen to nineteen years, the descriptions of the injuries were uncertain. In all of them the capsule and the labrum had been torn from the rim and the neck of the scapula. No attempt at repair had been made. Except in three cases, none had further recurrence after their activities had been restricted for eight weeks by an apparatus which prevented abduction and external rotation. In two of these three cases, a second operation was performed, the long head of the biceps and the coracohumeral ligament were passed through the head of the humerus, and the capsule was reattached to the rim of the glenoid, as described by Bankart.

The author has found, by observation under direct vision, that the best method of reducing dislocations is by downward traction and adduction, with the fist in the axilla (Fig. 13-A).

In no case in this series of twenty-seven was the axillary nerve injured.

CONCLUSIONS

Perhaps no far-reaching conclusions should be drawn from this small series of twenty-seven cases of acute anterior dislocation of the shoulder. However, it seems fair to say that:

1. The pathological findings in acute anterior dislocation of the shoulder are not the same in every case.

2. The injury depends upon the causative force. Hyperabduction will tear the capsule from the neck of the humerus and, if severe enough, will tear part or all of the attachment of the subscapularis tendon away from the humerus. If a force of impaction is added as the arm goes into abduction, the labrum glenoidale and the capsule will tear from the neck of the scapula, also in a longitudinal direction.

3. Reduction of acute anterior dislocations is accomplished with the least amount of trauma by traction and adduction, with the fist high in the axilla.

4. Most recurrent dislocations of the shoulder are the result of too early and too vigorous use of the shoulder, before the capsule has had time to heal and to reattach itself to the neck of the humerus or the neck of the scapula. An eight-week period of immobility in an apparatus which will prevent abduction and external rotation gives the best results.

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TABLE I

FINDINGS IN ELEVEN PATIENTS WITH POSTERIOR DISLOCATION OF THE SHOULDER

Case No	Name	Age and Sex	Etiology	Concomitant Fracture	Time from Injury to Diagnosis	First Treatment	Complication	Treatment Subsequent to Complication	Findings at Operation	Period of Immobilization	Results
1	R L	32 M	Trauma Picture fell on shoulder	None	10 hours First physician	Closed reduction, wire transfixion to acromion				3 weeks, Velpeau bandage	Excellent Normal shoulder 6 months after dislocation
2	C W	66 M	Epileptic convulsion	*Right* Large fragment from inferomedial margin of humeral head	4 days Treatment delayed until twelfth day	Closed reduction, failure Open reduction, wire transfixion to acromion			Organizing hemorrhage, large fragment broken out of inferomedial side of humeral head	3 weeks, Velpeau bandage	Good Abd restr 10° Ext rot restr 30%
				Left Large fragment from inferomedial margin of humeral head	4 days Treatment delayed until twelfth day	Open reduction, wire transfixion to acromion			Organizing hemorrhage, large fragment broken out of inferomedial side of humeral head	3 weeks, Velpeau bandage	Good Abd restr 15° Ext rot restr 35%
3	J C	35 M	Trauma Fell from moving locomotive	Small fragment from medial aspect of head, adjacent to shaft	4 months					4 months, concomitant compound fracture of elbow, same arm	Poor Painful shoulder Total loss of glenohumeral motion
4	J V	19 M	Trauma Fell from moving truck	Trough fracture in head	6 months	Open reduction and Nicola tenosuspension, 7 months after injury	Postoperative dislocation of head to anterior position	None	Dense scar Fibrillation of articular cartilage Trough fracture in humeral head	8 weeks, aeroplane cast	Poor Painful shoulder Total loss of glenohumeral motion
5	S E	64 M	Trauma Fell down cellar steps	Trough fracture in head	6 hours First physician	Closed reduction Velpeau bandage	Redislocation in Velpeau bandage Not recognized	Open reduction, on aeroplane splint 9 months after injury Dislocated anteriorly	Dense scar Fibrillation and erosion of articular cartilage Trough fracture	10 weeks after operation, aeroplane splint	Poor Painful shoulder Total loss of glenohumeral motion

TABLE I (Continued)

6	P J	20 M	Trauma Automobile accident	Small fragment from inferomedial margin of head	6 hours First physician	Closed reduction Velpeau bandage	Redislocation in Velpeau bandage Not recognized	Open reduction 5 weeks after injury	Dense scar Small bone fragment at inferior margin of glenoid Defect in head	6 weeks after operation, aeroplane splint	Fair Abd restr 10° Ext rot restr 50% Int rot restr 25%
7	N H	32 M	Convulsive seizure from electric shock	None	5 months	Open reduction and immobilization, 6 months after injury			Dense scar Marked degeneration of articular cartilage Groove in head	6 weeks, aeroplane splint	Fair Abd restr 15° Ext rot restr 50% Int rot restr 50%
8	G C	37 M	Epileptic convulsion Had brain tumor	Large fragment comprising ⅓ of articular surface of head	20 days Consultant	Closed reduction, unsuccessful		Open reduction, 25 days after injury	Organized hemorrhage Large loose fragment, comprising ⅓ of head, removed	6 weeks	Poor Painful shoulder Total loss of glenohumeral motion
9	D O'L	82 M	Trauma Fell down steps	None	2 months	Closed reduction 2 months after injury Velpeau bandage	Redislocated in Velpeau bandage	Closed reduction Arm immobilized in extreme int rot with forearm behind back for 3 weeks		5 weeks	Fair Abd restr 50° Ext rot restr 60% Int rot restr 20%
10	H T	36 M	Epileptic convulsion	Large fragment comprising most of head	12 hours	Closed manipulation	Large fragment of head fractured, most of head behind glenoid	Open reduction, 17 days after injury Fragment wired to upper end of shaft and head	Extensive hemorrhagic infiltration of tissues Large loose fragment of head behind glenoid	8 weeks	Fair Abd restr 35° Ext rot restr 30% Int rot restr 30%
11	J S	43 M	Trauma Arm twisted	None	24 hours First physician	Closed reduction Velpeau bandage				3 weeks	Good Abd restr 10° Ext rot restr 20%

Abd restr = abduction restriction Ext rot restr = external-rotation restriction Int rot restr = internal-rotation restriction

Fig. 1-A

Fig. 1-B

Fig. 1-C

Fig. 1-D

Roentgenograms, taken in four cases, show various types of fractures which may occur with posterior dislocation of the shoulder.
Fig. 1-A: Large fragment from inferomedial segment of head.
Fig. 1-B: Fracture of large segment of head.
Fig. 1-C: Fracture of lesser tuberosity.
Fig. 1-D: Small fragment from inferomedial segment of head.

PATHOLOGICAL FINDINGS

Detailed knowledge of the gross pathological changes in traumatic posterior dislocation of the shoulder is lacking. This hiatus in our knowledge results from the fact that (1) the lesion is infrequent, (2) when recognized early, open operation is rarely necessary, and (3) in the patients who have late surgical repair, the initial soft-tissue damage is obscured by dense fibrous-tissue repair.

The degree of gross disarrangement of the humerus and glenoid depends upon the violence of the force producing the injury. Cadaver experiments show that this dislocation can be produced by forced internal rotation of the arm in adduction. It is probable that in accidents there is a forcible upward thrust on the humerus as well. In those posterior dislocations which result from moderate violence, such as occur from muscle contraction in the epileptic and in ordinary falls, the head of the humerus lies beneath the acromion process, with the anatomical neck abutting against the posterior rim of the glenoid fossa. The lesser tuberosity of the humerus lies on the glenoid fossa. If there is a marked upward

thrust in the violence producing the injury, the head of the humerus may be forced more posteriorly under the spine of the scapula.

It is obvious that the extent of the soft-tissue damage will depend upon the force producing the dislocation. Moullin and Keith, in 1901, concluded from cadaver experiments that the ligaments and capsule were not injured, but that the dislocation was due to a separation and displacement of the glenoidal labrum. Observations of more value concerning the soft-tissue damage have been made by Rowe and Yee, Robertson and Stark, and Hindenach. These authors have all described the surgical treatment of recurrent posterior dislocation of the shoulder, which was the sequela of an original acute traumatic posterior dislocation. Rowe and Yee, in two patients, found the capsule separated from the neck of the scapula, and satisfactorily relieved the recurring dislocation by reattaching the capsule to the posterior glenoid margin after the manner described by Bankart for recurrent anterior dislocation. Robertson and Stark operated upon three patients with posterior dislocation. If a lax capsule was found posteriorly, relief of the chronic dislocation was effected by plicating and reattaching the capsule to the posterior margin of the glenoid. Hindenach found a loose capsule in one patient, and treated the condition by a posterior bone block. Both Hindenach and Rowe and Yee cite instances of patients who had not been relieved of recurring posterior dislocation of the shoulder by a Nicola type of operation. In the cases reported by these authors, the glenoidal labrum was not found to be detached, although Rowe and Yee noted erosion of its posterior inferior surface. It seems probable from these observations, therefore, that, in acute posterior dislocation of the shoulder, there is a tear in the posterior capsule or an avulsion of the posterior capsule from the neck of the scapula.

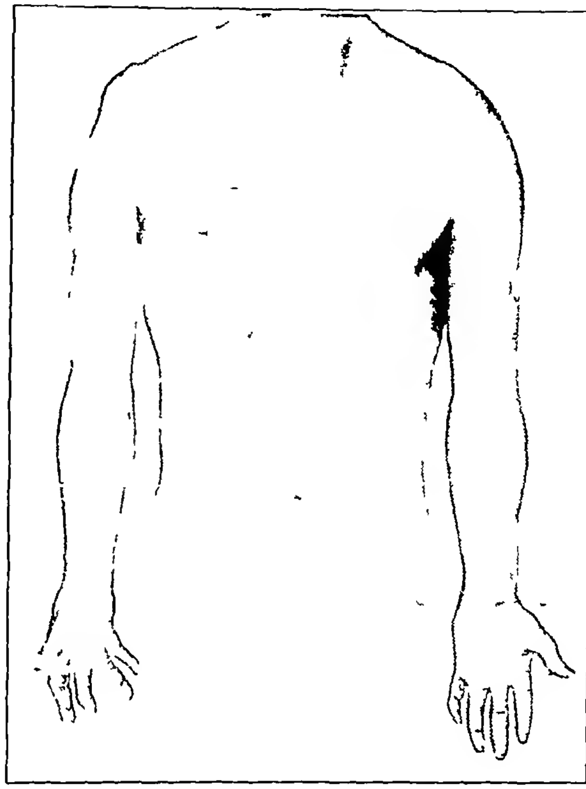

FIG. 2

Drawing of clinical appearance of posterior dislocation of shoulder, showing prominent coracoid process and anterior margin of acromion process, bulge of humeral head posteriorly and flattened deltoid, partial internal rotation of humeral condyles, and inability of patient to supinate back of hand flush to table.

Damage to the bone and articular cartilage of the humeral head varies with the violence producing the dislocation (Figs. 1-A, 1-B, 1-C, and 1-D). In those dislocations resulting from a minimal amount of violence, there may be only an eroded area in the articular cartilage of the humeral head. A vertical trough type of fracture may appear where the soft cancellous head of the humerus comes against the more dense glenoid rim. The lesser tuberosity of the humerus may be separated from the shaft, or a fragment of bone may be avulsed from the humeral head at its junction with the shaft. When the trauma producing the dislocation is severe and the force continues after the head has become wedged back of the glenoid rim, a complete fracture of the neck of the humerus may result, so that the proximal end of the shaft is pulled up over the face of the glenoid, with the head alone lying posteriorly. Other bizarre patterns of fracture may result when the force producing the dislocation is long and continuous.

Injury to nerve trunks does not accompany posterior dislocation, as the excursion of the head of the humerus is not great and it does not directly contuse the nerves or

stretch them Its direction of dislocation is away from, rather than toward, nerve trunks

Extensive hemorrhage and infiltration of soft tissues with blood follows this injury, and marked swelling is common When these dislocations are unrecognized and late open reduction is done, there is marked fibrosis about the humeral head and the glenoid, so that identification of structure is difficult In those late dislocations associated with fracture, extensive calcification may be present in the soft tissues, and new-bone formation may be present about any fragments

CLINICAL PICTURE

In the early case of acute posterior dislocation of the shoulder, and also in the old unrecognized case of retroglenoid dislocation, there is no difficulty in diagnosis The diagnosis is not obvious, however, during the period of swelling produced by extensive extravasation of blood under the deltoid muscle

In the acute injury before swelling develops, and also in the old unrecognized case, the appearance of the shoulder is quite striking, especially with the patient lying supine Abnormal prominence of the coracoid process and of the anterior margin of the acromion is present, with flattening of the deltoid muscle belly (Fig 2) At the posterior margin of the acromion process, where the deltoid normally begins to flatten, there is a prominent globular bulge This bulge, under the posterior margin of the acromion, can be felt to be the head of the humerus The condyles of the elbow are in a position of moderate internal rotation With the patient supine, the forearm cannot be supinated, so that the dorsum of the hand lies flush with the table, as a result of the loss of external rotation in the shoulder No glenohumeral motion can be elicited, all motions of the humerus moving the scapula

ROENTGENOGRAPHIC FINDINGS

Posterior dislocation of the shoulder is frequently missed, because of inadequate roentgenographic examination of the shoulder and because of unfamiliarity with the normal shoulder Anteroposterior roentgenograms of the normal shoulder present a decidedly different picture with the humerus in external rotation than with the humerus in internal rotation When the humerus is in external rotation, the greater tuberosity is seen prominently in profile, forming the lateral margin of the head, and the lesser tuberosity is just medial to it There is also a half-moon shadow on the medial contour of the humeral head, where the shadow of the glenoid is superimposed on the humerus The lower third of the glenoid cavity is covered by the medial border of the humeral head

In a posterior (retroglenoid) dislocation of the humeral head, the humerus is in extreme internal rotation (Figs 3-A, 3-B, and 3-C) Various authors have called attention to changes appearing in the anteroposterior roentgenogram Bonadeo Ayrolo noted loss of the sharp outline of the greater tuberosity and the disappearance of the half-moon shadow of the superimposed glenoid and humerus Rendich and Poppel called attention to the fact that, in a posterior dislocation, the lesser tuberosity of the humerus forms the medial border of the roentgenographic shadow of the humeral head, and also that the lower third of the glenoid may be exposed in the anteroposterior roentgenogram of a posterior dislocation Mynter pointed out that, in an anteroposterior roentgenogram of a patient with posterior dislocation, the greater tuberosity lay "directly under and behind the coracoid process" These are all valuable signs and, when present, certainly suggest a derangement of the normal glenohumeral relationship However, the normal variations in contour of the head of the humerus make them unreliable In addition, many of these changes can be simulated if an anteroposterior roentgenogram is taken with the humerus in extreme internal rotation, or with the elbow supported in a Velpeau bandage

The definite and unmistakable diagnosis of posterior dislocation of the shoulder is made by obtaining both anteroposterior and lateral roentgenograms (Fig 4) The lateral roentgenogram is best obtained by holding the plate over the top of the shoulder and

directing the ray into the axilla (Figs. 5-A, 5-B, and 5-C). This requires moderate abduction of the humerus, but is generally possible without too great discomfort. A less satisfactory lateral view may be obtained by directing the ray through the thorax, with the uninjured arm over the head and the plate on the lateral aspect of the injured shoulder.

In the lateral (axillary) roentgenogram of a posterior dislocation, the humeral head is seen to lie posterior to and outside the glenoid cavity, and to be widely separated from the coracoid process. In an anterior dislocation of the humeral head, the lateral roentgenogram shows the head anterior to the glenoid, but, in contrast to a posterior dislocation, the head is close to, or snugged up against, the coracoid process.

Anteroposterior stereoroentgenograms of the shoulder, when viewed by a person with well-developed stereopsis, reveal the posterior dislocation. Except by a roentgenologist who daily views stereoroentgenograms, the posterior dislocation is apt to be missed. The shoulder joint has very little depth, and does not lend itself well to stereoroentgenography.

TREATMENT

Successful treatment of posterior (retroglenoid) dislocation of the shoulder depends upon three factors: (1) early recognition of the condition, (2) prompt reduction of the humeral head to its normal relationship with the glenoid, and (3) maintenance of the reduction until the capsular structures have healed.

In the first few hours after the injury,

Fig. 3-A

Fig. 3-B

Fig. 3-C

Anteroposterior roentgenograms of shoulder.

Fig. 3-A: Normal shoulder in external rotation with prominent outline of greater tuberosity, semilunar shadow of humerus superimposed on glenoid, and lower third of glenoid covered by humerus.

Fig. 3-B: Posterior dislocation with loss of sharp outline of greater tuberosity, lower third of glenoid is uncovered. Semilunar shadow has not disappeared.

Fig. 3-C: Normal shoulder in internal rotation, showing loss of shadow of greater tuberosity, lesser tuberosity is in glenoid fossa.

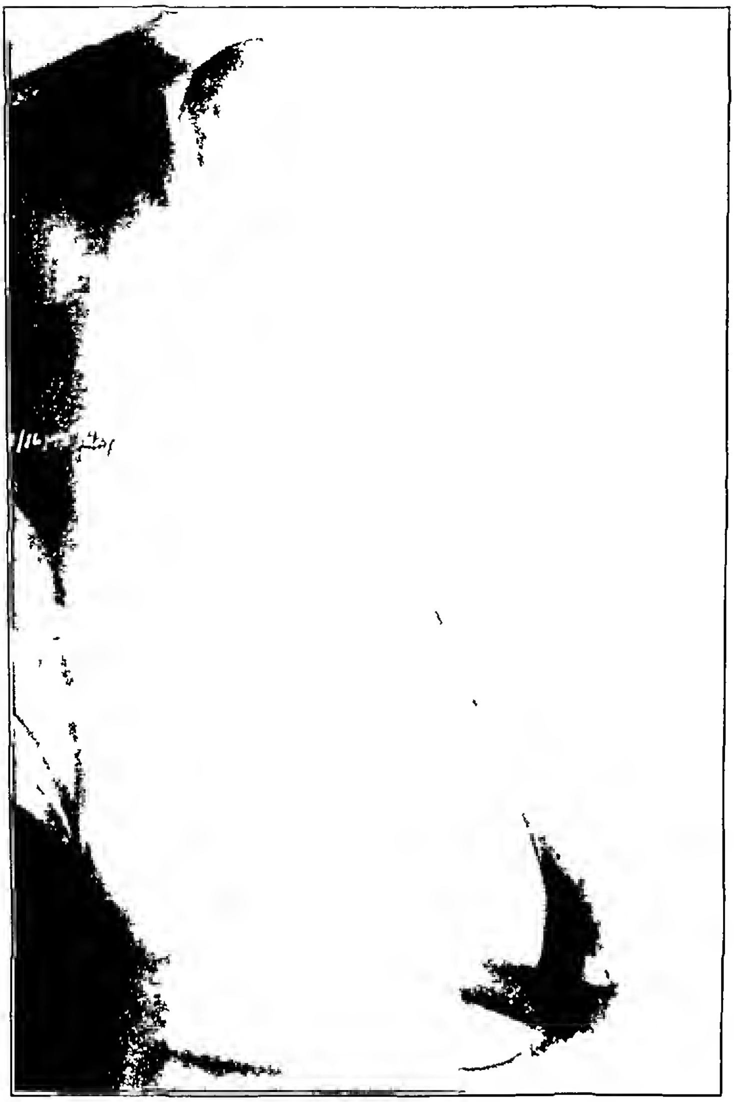

FIG 4

Anteroposterior roentgenogram of posterior dislocation of shoulder, taken on day of injury, showing loss of outline of greater tuberosity, loss of semilunar shadow on medial side of head, and partial bareness of lower third of glenoid This patient also had compound fracture of elbow, and the posterior dislocation of the humeral head was overlooked

reduction is easily effected, with anaesthesia adequate to overcome muscle spasm Gentle *traction on* the humerus, with the elbow flexed, and simultaneous gentle manipulation to increase the internal rotation, combined with pressure on the head of the humerus, cause the head to fall into its normal relationship to the glenoid The reduction, however, is unstable, and dislocation easily recurs as a result of motion or may result spontaneously from muscle spasm, even though the arm is immobilized Of four patients treated by closed reduction and bandaging the arm to the side, spontaneous redislocation occurred in three The position of greatest stability after reduction is one of internal rotation of the humerus In one of these patients in whom a redislocation occurred, it was possible to maintain the second reduction by immobilizing the humerus in extreme internal rotation, with the forearm bandaged behind the back for three weeks (Figs 6-A and 6-B) This is a very awkward, disabling, and uncomfortable position to maintain for a long period of time

The following method has been used by the authors to ensure maintenance of the reduction in two patients with three dislocations of the shoulder It has been found to be safe and comfortable

The first patient was a man, thirty-two years old, who suffered a posterior dislocation of the left shoulder as a result of trauma (Fig 7-A) He was subjected to a closed reduction ten hours after the injury With the patient under anaesthesia, the head of the humerus was easily repositioned, however, with the forearm over the abdomen, the head became redislocated The shoulder was again easily reduced With the humeral head held in normal relation to the glenoid by pressure back of it, and with the forearm in front of the abdomen, two wires were drilled through the intact skin over the acromion and through the head of the humerus in a cruciate fashion The ends of the wires were left projecting through the skin over the acromion (Fig 7-B) The wires were left in place for three weeks, with the arm held to the side in a Velpeau bandage, they were then removed and physical therapy was instituted (Figs 7-C and 7-D) This patient did not have a concomitant fracture, and five months after injury he had normal motion and muscle power in *the shoulder* and was taking part in athletics

The second patient was a man, sixty-six years old, who suffered bilateral posterior

Fig. 5-A

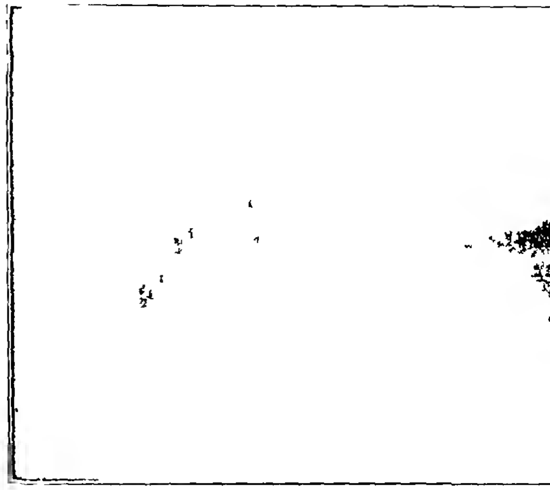

Fig. 5-B

Lateral (axillary) roentgenograms of shoulder, taken with arm abducted, plate on top of shoulder, and ray directed into axilla.

Fig. 5-A. Normal shoulder, with humeral head in glenoid fossa.

Fig. 5-B. Posterior dislocation, with humeral head posterior to glenoid fossa and remote from coracoid process.

Fig. 5-C. Anterior dislocation, with humeral head in front of glenoid fossa and snugged up against coracoid process.

Fig. 6-A. Posterior view of humerus in position of extreme internal rotation, necessary to prevent redislocation in one patient.

Fig. 6-B. Photograph of arm in Velpeau bandage behind back to maintain internal rotation.

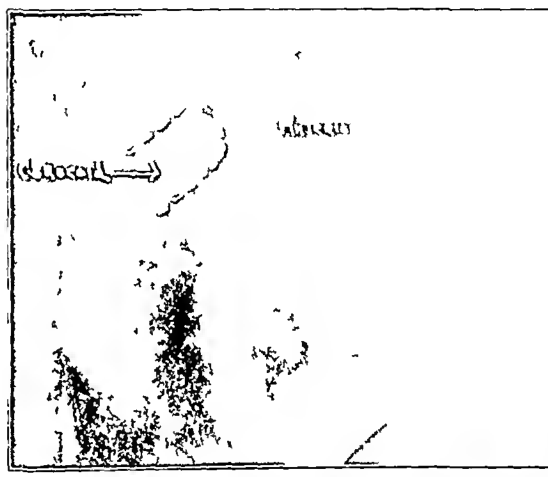

Fig. 5-C

Fig. 6-A

Fig. 6-B

dislocation of the shoulder in a convulsive seizure. There was a *concomitant avulsion fracture* of a fragment from the inferomedial segment of each humeral head. The condition was

FIG. 7-A

FIG. 7-B

Roentgenograms of thirty-two-year-old man who suffered posterior dislocation of shoulder without fracture.

Fig. 7-A: Lateral (axillary) view. (X-ray has been reversed.)

Fig. 7-B: Anteroposterior roentgenogram after reduction, with humeral head transfixed to acromion process by cruciate wires.

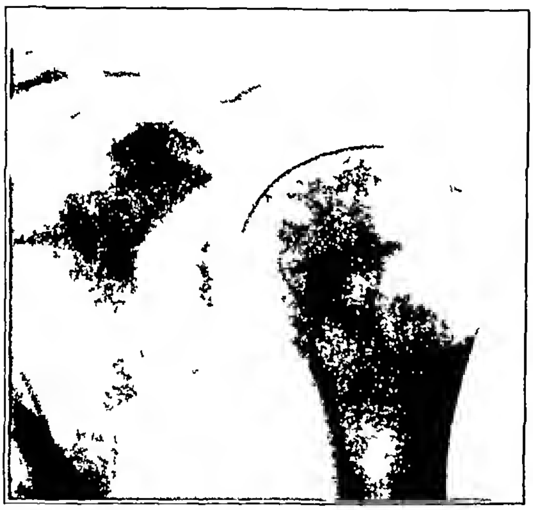

FIG. 7-C

FIG. 7-D

Anteroposterior and lateral (axillary) roentgenograms taken six weeks after reduction. The cruciate transfixion wires have been removed.

not recognized immediately, and the patient did not receive treatment until the twelfth day after injury. An attempt at closed reduction was unsuccessful, and open reductions were done on both shoulders at the same time, anaesthesia being used.

At operation, two large, loose fragments of bone, one of which had been fractured from each humeral head, were removed. With the shoulder capsules exposed, it was impossible to find any position in which the humeral heads were stable in the glenoid cavities. The head of each humerus was held in normal relationship to the glenoid, the elbow being flexed and the forearm being placed over the abdomen. Two wires were then drilled, in cruciate fashion, through the top of each acromion process and through the head of each humerus, transfixing the humeral heads to the acromion processes. The incisions were closed and the arms were loosely bandaged in front of the abdomen, with the elbows flexed. During the three weeks that the wires were left in place, the patient was comfortable. At the end of three weeks the wires were removed by the ends, which projected through the skin over the acromion. Each arm was placed in a sling, and physical therapy was started.

This patient recovered a good range of motion in both shoulders. Nine months after

the injury he returned to heavy work. He had loss of abduction of 10 degrees and a 30 per cent. loss of external rotation in each shoulder.

This procedure is simple, comfortable for the patient, and avoids the possibility of spontaneous redislocation of the head of the humerus.

Treatment of an old unrecognized retroglenoid dislocation of the shoulder requires open reduction. It has been stated by *Thomas* that good function may be expected in an old unreduced posterior dislocation, due to the formation of a new fossa on the scapula. This statement does not seem logical. All patients in this group with old unreduced dislocations complained of pain down the arm to the elbow, and none had any useful glenohumeral motion.

If the dislocation has been unrecognized for an appreciable period of time, widespread fibrosis of the pericapsular structures is always present. Extensive dissection is necessary to mobilize the humeral head. After the head has been freed, a position of stability in the glenoid is always difficult to find. Wire transfixation of the humeral head to the acromion should be used.

In this group of patients, four were subjected to late open reduction. In two of these patients an anterior dislocation resulted, which might have been avoided had acromiohumeral transfixion been used. A Nicola tenosuspension failed to prevent the anterior dislocation in one patient.

Arthrodesis of the shoulder was not resorted to in this group of patients. Arthrodesis should probably be done in a posterior dislocation of very long standing, in a young individual, when the articular cartilage of the humeral head and glenoid fossa is so severely damaged that a satisfactory joint is improbable.

PROGNOSIS

Posterior dislocation of the shoulder, uncomplicated by fracture, when recognized early and treated promptly and adequately, can be expected to result in normal recovery of motion in the glenohumeral joint. Those posterior dislocations which have a concomitant avulsion fracture or trough fracture will also yield a satisfactory glenohumeral joint when recognized early and treated adequately. However, moderate loss of abduction and rotation should be anticipated if a fracture is present.

It is probable that, despite prompt and adequate treatment, recurrent posterior dislocation of the shoulder will develop in a few patients. Posterior dislocation of the shoulder, which is unrecognized and comes to treatment weeks after the injury, requires open surgical intervention. The result is likely to be poor, with marked loss of motion in the glenohumeral joint and a painful shoulder, unsuited for strenuous activity.

CONCLUSIONS

1. Posterior dislocation of the shoulder is an infrequent injury. It may result from trauma or from convulsive seizure.

2. Because of the infrequency of this injury, and because of the failure to obtain both anteroposterior and lateral (axillary) roentgenograms of the shoulder joint, the dislocation is frequently unrecognized for a long period of time.

3. Prompt recognition and treatment of posterior dislocation of the shoulder by closed manipulation yield excellent results.

4. Even with early prompt reduction, however, the replacement is unstable and there is great danger of spontaneous redislocation.

5. The danger of redislocation can be avoided by the simple expedient of transfixing the reduced humeral head to the acromion process with cruciate wires. This does not require an open operation.

6. Failure of early recognition necessitates open operative intervention. The results of late treatment are poor.

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DISCUSSION

Dr Harrison L McLaughlin, New York, N Y I would like to emphasize one point brought out by Dr Nicola's paper In two of the twenty-seven cases (between 7 and 8 per cent), the dislocation resulted from manipulation of a stiff shoulder Several years ago, Dr Neviaser showed the damage that manipulation could do to the shoulder mechanism In our Clinic, a great deal of satisfaction was experienced by the disruption of what we took to be adhesions when a stiff shoulder was manipulated Manipulation was done in a small series with the shoulder exposed to direct vision, and we found to our surprise that what we had interpreted as a disruption of adhesions was actually disruption of the normal structures of the shoulder Manipulation of the shoulder is a dangerous procedure, followed by uncertain results, it should be approached with caution, and, when done, it should be carried out with great gentleness

I must disagree wholeheartedly with Dr Nicola's final conclusion that most recurrent dislocations of the shoulder result from too early and too vigorous use of the shoulder before the capsule has had time to heal and to reattach itself to the neck of the humerus or the neck of the scapula He stated that the best results followed an eight-week period of immobilization In the last twenty cases he reported, the pathological lesion was identified These shoulders were immobilized for eight weeks and in three of them, or 15 per cent , the dislocation recurred It seems to me that, rather than proving the point, he has adequately demonstrated that prolonged immobilization will not prevent recurrence This has been substantiated by our own investigations, which suggest that recurrence depends upon the primary damage to the shoulder structures resulting from the original trauma It is because of variations in the detail of this injury that no single operation will cure all cases of recurrent dislocation of the shoulder

Dr Wilson and Dr McKeever have done well in demonstrating the frequency with which the diagnosis of posterior dislocation is missed The single early case which we encountered, however, did not require any method, such as the transfixion wires advocated by these authors, in order to maintain reduction

Dr Nicholas J Giannestras, Cincinnati, Ohio My experience is limited to one case of recurrent posterior dislocation of the shoulder This was seen while in the Armed Services, and the following procedure was carried out After exposure through the posterior approach, as described by Stark, the capsule was found to be torn from the glenoid, and by internal rotation the shoulder could be dislocated at will The capsule was accordingly sutured to the edge of the glenoid process with interrupted cotton sutures, but, in order to maintain reduction and eliminate tension upon the capsule, it was necessary to hold the shoulder in a position of external rotation Therefore, after closure of the muscular and cutaneous layers, the extremity was held against the side of the thorax in external rotation with the elbow in complete flexion It was immobilized in this position for four weeks by the use of adhesive tape and flannel bandages At the end of this time active motion and physical therapy were instituted, and when this patient was last seen, sixteen months after operation, he had complete recovery of motion

I appreciate the fact that the method advocated by Dr Wilson and Dr McKeever makes security doubly certain by the use of the transfixion wires I should like to ask, however, if they do not feel that, with the extremity held in complete external rotation, sufficient stability could not have been achieved by immobilization in the acute cases which they reported, thereby obviating the use of the transfixion wires, and, in those cases requiring surgery, whether a posterior approach would not have been the better one

We, who perform the manoeuvre of Kocher, recognize that the gentle external rotation of the arm is the secret to successful reduction, and that replacement of the head occurs while one is externally rotating the arm

(Continued on page 180)

THE TREATMENT OF RECENT DISLOCATIONS AND FRACTURE-DISLOCATIONS OF THE SHOULDER

BY HENRY MILCH, M.D., NEW YORK, N. Y.

Recent interest in dislocation of the shoulder has been largely devoted to treatment of the recurrent type of lesion. The acute dislocation has been taken for granted, and treatment by the manipulation which Kocher described in 1870 is still recommended as the method of choice. While it represented a distinct advance in its time, the method should now be discarded as dangerous and unphysiological.

Although Cubbins and his associates insist that the biceps tendon offers the chief obstruction to reduction of the dislocated shoulder, the resistance has generally been attributed to the tonic contraction of the subscapularis muscle. Stretching of this muscle with consequent release of the humeral head is the primary objective of Kocher's manoeuvre. Theoretically, it would seem to offer a satisfactory, although brutal, solution to the problem, but the danger lies in the fact that fracture of the shaft of the humerus may be the inadvertent sequel. Almost invariably the fracture line is oblique, running from below the lesser tuberosity upward and outward toward the tip of the greater tuberosity. The humeral head and lesser tuberosity constitute the smaller fragment, the shaft and the greater tuberosity constitute the larger fragment. The constancy of this effect must be attributed to the stress exerted by external rotation of the whole arm against the internal rotatory action of the subscapularis, acting upon the lesser tuberosity. Where the magnitude of this force exceeds the strength of the bone, fracture takes place.

In order to avoid this danger, the writer suggested a method which appears to be almost identical with the method attributed to Sir Robert Jones [6] for the treatment of fracture-dislocations of the shoulder, but, where Jones was concerned primarily with aligning the humeral shaft with the axis of the dislocated head, this method has a deeper justification in the anatomical arrangement of the shoulder-girdle musculature. It is the only method in which the antagonism of individual muscles can be overcome, and in which the force used to overcome muscle pull is in the same direction as that needed to effect reduction.

In the so-called "anatomical position", with the humerus at the side, the direction of the various muscles around the shoulder girdle seems to be completely haphazard (Fig. 1). Some run upward and outward, others run downward and outward, while still others run either directly upward or downward. The resultant of the shoulder-girdle muscles, acting synergistically, is directed principally in a medial direction. With the arm in the anatomical position, this resultant exerts its maximum effect at a large angle, transverse to the longitudinal axis of the bone. The force which must be employed to conquer the resistance of the subscapularis must, at the same time, be large enough to overcome the medially acting components of the other muscles. When the tensile strength of the bone is inadequate to meet this stress, fracture results.

When the arm is placed in the overhead or fully abducted position, an entirely different situation is created. From wherever they arise, whether from in front or in back, all the shoulder muscles run directly upward to be inserted into the humerus or into the axis of the extended upper extremity. In a general manner, all these muscles can be roughly divided into three or four groups. Each of these may be considered as lying upon the surface of separate cones, the apices of which all lie upon a straight line. This straight line is collinear with the axis of the arm and its extension, the forearm (Fig. 2).

The innermost and shortest of these cones is formed by the subscapularis, the supraspinatus, the infraspinatus, and the teres minor. Together, their insertions into the head

of the humerus form the musculotendinous cuff, described by Codman The second of these groups comprises the latissimus dorsi, the teres major, and the pectoralis major The apex of this larger and more superficially situated conical group is placed more distally upon the shaft of the humerus The third group consists of the deltoid and the coracobrachialis The fourth and longest group is made up of the biceps and the triceps brachii, which insert into the radius and ulna, respectively

Of all the positions which the humerus may assume, the overhead position is the only one in which all these muscles run in the same general direction The resultant of the shoulder muscles is coaxial with the humerus, and the transverse or fracturing component

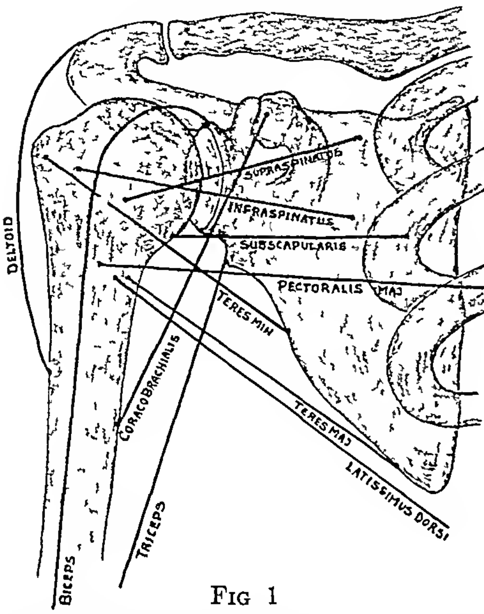

FIG 1

Drawing of arm in the "anatomical position" with the course of the perihumeral muscles inked in black Note angle which adducted humerus makes with axillary border of scapula

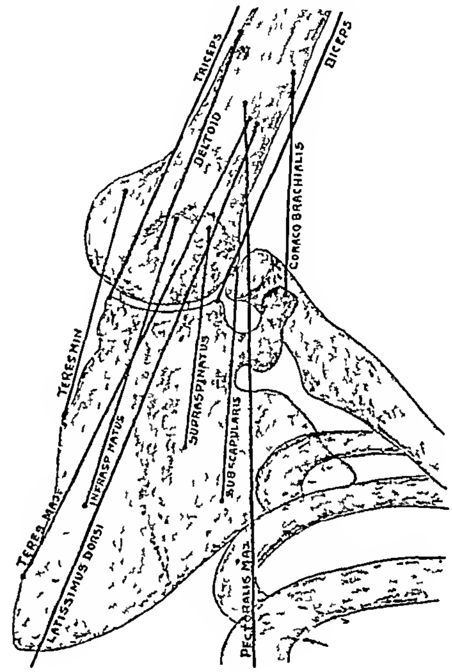

FIG 2

Fig 2 The same arm in complete overhead abduction The scapula has rotated on the chest The humerus is collinear with the axillary border of the scapula All the perihumeral muscles fall into four groups of cones, the apices of which all lie in the axis of the humerus

is reduced to zero Phylogenetically, this is significant, because the overhead attitude is the position of arboreal brachiation This is the position in which the resultant of the total muscular effort acts to oppose the downward force of gravity, which tends to tear the trunk away from the limb-clutching arms It is the only position in which a single force, exerted along the axis of the humerus, is accurately directed to overcome each and all of the muscle actions at the same time For this reason, it has been chosen as the position in which reduction of dislocation of the shoulder should be undertaken, in preference to the anatomical position employed by Kocher

The manoeuvres employed have been previously described as follows [5]

"The patient lies in the supine position, while the surgeon takes his position on the side of the dislocation In a right sided dislocation the surgeon places his right hand upon the patient's right shoulder, so that the fingers find firm support on the top of the shoulder, while the thumb is braced against the dislocated humeral head The right hand fixes the head as the left hand gently abducts the arm into the overhead position During this maneuvre the head of the humerus is supported so that it cannot move from its dislocated position As a consequence, instead of moving downward as the arm moves upward, the head rotates in place In this manner the tendency to further stretch already stressed nerves is obviated Once the arm has been brought into complete abduction in this overhead position, all cross-stresses exerted by all the muscles have been elimi

nated, the head can be gently pushed over the rim of the glenoid and the dislocation reduced " (Fig 3)

The application of the method to acute dislocation, whether associated with fracture or not, is illustrated in the following cases

CASE 1 E K, housewife, aged seventy-seven, was first seen April 25, 1940 Four days before, she had fallen and suffered "a subcoracoid dislocation of the shoulder, associated with a fracture of the greater tuberosity of the humerus" An unsuccessful effort had been made to reduce the dislocation

On April 25, the patient was admitted to the hospital for a reduction under general anaesthesia Just before this was started, a final attempt to reduce the dislocation was made The patient's arm was slowly brought into the completely overhead position On several occasions, when the patient became fearful, progress was stopped, and the patient was soothed and cajoled into indolent cooperation Once the arm had been brought into complete abduction, the head was gently pushed into the glenoid fossa All clinical signs indicated complete reduction, and this was confirmed by the roentgenogram A Velpeau bandage was applied for several days On April 27, the patient was discharged with her arm in a sling Motion was restricted for a matter of several weeks, but thereafter the patient gradually resumed her usual activities without any disability

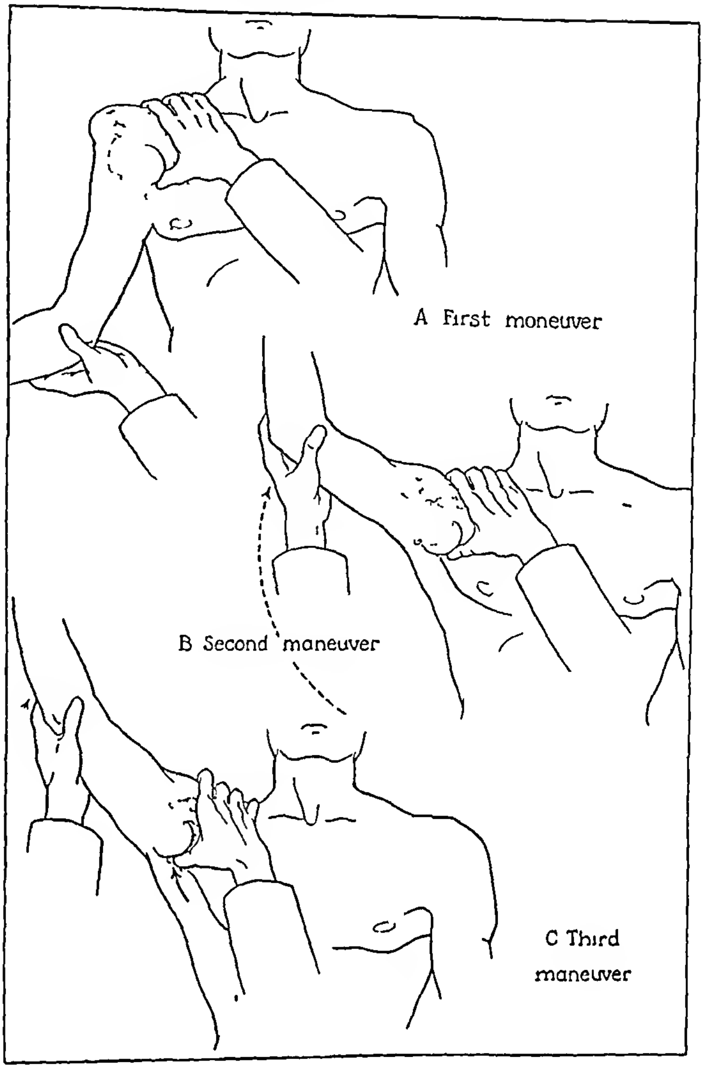

FIG 3

Steps in the reduction of dislocation of the right shoulder by the overhead abduction-traction-pulsion method (Reproduced from *Surgery*, 3 739, 1938)

CASE 2 M K, housewife, aged sixty-four, was seen on September 21, 1942 Early that morning, she had fallen and suffered a subcoracoid dislocation A local physician had unsuccessfully attempted to reduce this dislocation under general anaesthesia Some hours later the patient was brought to New York

The appearance of the arm was typical, and there was no evidence of nerve injury The roentgenogram disclosed a subcoracoid dislocation of the proximal end of the humerus, associated with a comminuted fracture of the greater tuberosity of this bone There was outward displacement of the free fragments

Because of the previous failure of attempted reduction under general anaesthesia, it was believed that great difficulty would be met in reducing this dislocation Nevertheless, it was determined to make one effort by use of the method under discussion No anaesthesia was employed The head of the humerus was fixed, while the arm was elevated with the greatest gentleness When the arm had reached the overhead position, reduction was accomplished immediately, and even without the necessity of pushing the head over the glenoidal labrum The patient experienced prompt relief of pain, with immediate restoration of the range of motion She was given a sling and was permitted to be up and about, but was cautioned against excessive abduction of the arm A roentgenogram taken on the following day was reported as showing "correction of pre-existing luxation of the humerus", with excellent alignment of the fragments at the site of the comminuted fracture of the greater tuberosity Three days later, on September 26, it was noted that the patient was actively moving the arm There was no evidence of brachial fixation or nerve injury On the following day, the patient was discharged to her home in Connecticut

The following case is of special interest because of the length [illegible] which had elapsed before closed reduction by manipulation was successful [illegible]

Fig 4-A

Fig 4-B

Fig 4-A Case 3, J R Subcoracoid dislocation of right shoulder, after six weeks Note calcification in] tissues along outer side of the humeral neck
Fig 4-B After closed reduction

believe that after the lapse of three to four weeks, manipulative reduction, presumably by the Kocher method, is fraught with unusual danger of fracture After four to six weeks have passed, an unreduced dislocation of the shoulder was considered by Campbell to present a positive indication for open operation in practically all cases This was not found to be necessary in the following instance

Case 3 J R, housewife, aged seventy-six, was first seen on November 18, 1945 She gave a history of a fall on her outstretched right arm on October 22, 1945 She was taken to a hospital in Florida, where an attempt at reduction was made under general anaesthesia Despite this, the patient continued to complain of pain so severe that she had to be given hypodermic medication At the end of two weeks she was discharged to the care of her family physician, but he referred her back to the hospital The patient was then given an intravenous anaesthesia, and another attempt at reduction was made This, too, appears to have been unsuccessful, and roentgenograms taken on November 14, 1945, still showed a "subcoracoid dislocation" (Fig 4-A) The patient thereupon came to New York

During her trip north, the patient contracted a cold, and upon her admission to the hospital she presented signs of inflammation at the bases of both lungs posteriorly Because of the presence of the pulmonary signs, the medical consultant advised against surgical procedures Therefore, it was not until November 28 that the patient could be given a general anaesthetic

Fig 5-A

Fig 5-B

Fig 5-A Case 4, R M Fracture-dislocation of left shoulder
Fig, 5-B, After closed reduction

To avoid the possibility of fracture or damage to the neurovascular structures, the arm was abducted with great care. No serious difficulty was experienced in getting the arm into the overhead position, but even strong pressure against the head did not effect reduction. At this point the shoulder was braced and, while gentle traction was exerted upon the abducted arm, firm pressure was maintained against the head of the humerus. Almost as soon as the combined traction and pulsion was applied, the head of the humerus slipped over the glenoidal rim and the arm could be brought to the side in a normal manner.

A postreduction roentgenogram (Fig. 4-B) was reported as showing almost complete correction of pre-existing subcoracoid dislocation of the humerus. In the soft tissues external to the proximal extremity of the humerus, there was an ossifying process. The patient made an uneventful recovery and was discharged from the hospital on December 9, 1945, with a fairly satisfactory range of motion. Under physical therapy, mobility was gradually increased, so that by the time she returned to her home in Florida, she had an almost normal range of motion.

In August 1946, the patient again fell upon her right shoulder. Because of the pain and limitation of abduction, she feared a recurrence of the dislocation and immediately came to New York, but a roentgenogram disclosed a fracture of the greater tuberosity without any displacement. The upper end of the humerus occupied its normal position in the glenoid fossa, and the calcification previously noted had entirely disappeared. The patient was treated by means of a sling, and made a completely uneventful recovery with normal range of motion.

Because of the extremely gentle manipulation employed, the possibility of danger either to nerves or blood vessels is minimal, and injury to them has not been encountered. In all probability, the nerve injuries which are attributed to the method of reduction are coincident with the dislocation. These occur in about one of every seven cases of so-called simple dislocation. In view of the legal implications which may be involved, no dislocation of the shoulder should be reduced until a preliminary and careful investigation for nerve involvement has been made.

Not even an apparently simple dislocation of the shoulder should be treated without roentgenographic examination. Contrary to the opinion of some authorities, fracture of the greater tuberosity occurs in over 10 per cent. of all the cases. While this is not usually of great significance, such a fracture fragment may be interposed between the glenoid fossa and the humeral head and so defeat the most skillful and conscientious efforts at reduction. Visualization of a fractured glenoid rim may forewarn the surgeon against too optimistic a prognosis. Above all, the roentgenogram is of value in the diagnosis of fracture-dislocation. In the presence of extensive hemorrhage, particularly if the patient is seen after the lapse of several days, the clinical diagnosis of fracture-dislocation may present the utmost difficulty.

Because of the impossibility of controlling the small capital fragment, the Kocher manipulation is not only foredoomed to failure, but may be fraught with consequences of a more serious nature. It is in such instances that methods other than the classical have been successfully instituted. This is illustrated in the following cases.

CASE 4. R. M., aged twenty-seven, was admitted to the hospital October 30, 1937, shortly after he had fallen down a flight of stairs, landing on the outstretched left hand, with the elbow held in extension. He complained of severe pain in the left shoulder, radiating down to the posterior aspect of the elbow. In addition, he noted a sensation of numbness in the left hand.

The patient presented the typical clinical appearance of a subcoracoid dislocation of the left shoulder. There was a well-defined ulnar-nerve lesion with definite signs of motor weakness.

The roentgenogram (Fig. 5-A) revealed an oblique fracture of the upper end of the humeral shaft with subcoracoid dislocation of the capital fragment.

Under local anaesthesia and by the method described here, reduction was accomplished without difficulty. The patient's arm was immobilized in a Velpeau bandage. A postreduction roentgenogram (Fig. 5-B) disclosed reduction of the dislocation with excellent reposition of the fractured fragments. Within a week after the reduction, return of some sensation in the ulnar-nerve distribution was noted; after about two weeks, sensation was almost normal, except for some dysaesthesia. This ultimately disappeared, with complete restoration of motion in the shoulder and return of motor power in the muscles supplied by the ulnar nerve.

CASE 5. T. M., aged forty-six, was first seen on January 2, 1947, several days after he had fallen and injured his right shoulder. On the following day, a roentgenogram revealed a fracture-dislocation of the right shoulder.

Examination disclosed the characteristic clinical picture of subacromial dislocation. The roentgenograms

revealed a comminuted fracture of the surgical neck of the humerus with a subcoracoid dislocation of mild degree (Fig 6-A)

Because of the fracture, the possibility of using the Kocher manoeuvre for reduction of the dislocation could not be considered, and it was determined to attempt reduction by the method of overhead traction pulsion Under gas, oxygen, and ether anaesthesia, the arm was gently brought into the complete overhead position The dislocation was promptly reduced with hardly any force, and the arm was brought to the side (Fig 6-B) A hanging plaster-of-Paris cast was then applied to the arm and forearm As soon as the patient had recovered from the anaesthesia, he was permitted to be up and about He was discharged from the hospital on January 5, 1947

The hanging plaster was left on for a little over five weeks, after which time physical therapy and active motions were begun Function was gradually restored, so that by the end of April the patient was able to return to his usual duties as a police officer

CASE 6 R K, aged sixty-four, was seen on July 7, 1947, shortly after she had slipped and fallen on he

FIG 6-A

FIG 6-B

Fig 6-A Case 5, J M Comminuted fracture of the surgical neck with subcoracoid dislocation on the right side
Fig 6-B Immediately after reduction

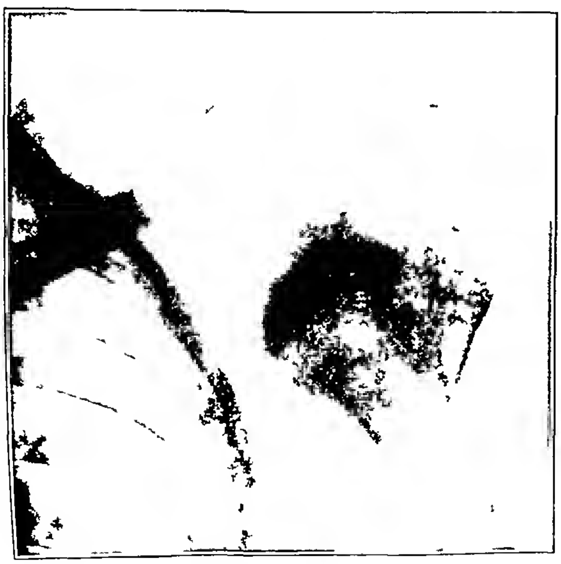

FIG 7-A

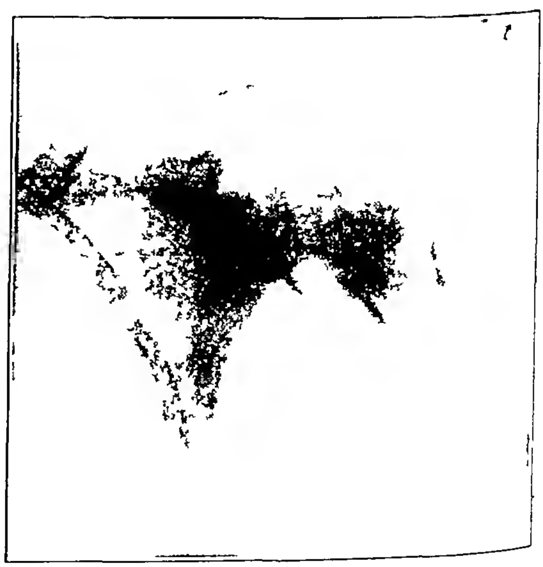

FIG 7-B

Fig 7-A Case 6, R K Fracture-dislocation of left shoulder before reduction
Fig 7-B, After reduction

outstretched left arm. The patient presented the typical appearance of a dislocation of the shoulder. There were no signs of any nerve involvement. The roentgenogram (Fig. 7-A) disclosed a subcoracoid dislocation of the head, with a longitudinal fracture of the greater tuberosity and a transverse fracture of the surgical neck of the humerus.

Because of the patient's extreme nervousness, the use of gas-oxygen anaesthesia was deemed necessary. As soon as primary analgesia had been obtained, the arm was gently manipulated into the overhead position and reduction was accomplished with almost no force (Fig. 7-B). The arm was immobilized in a Velpeau bandage, but slight active flexion and extension were begun within a few days. At the end of three weeks, active graded exercises were instituted.

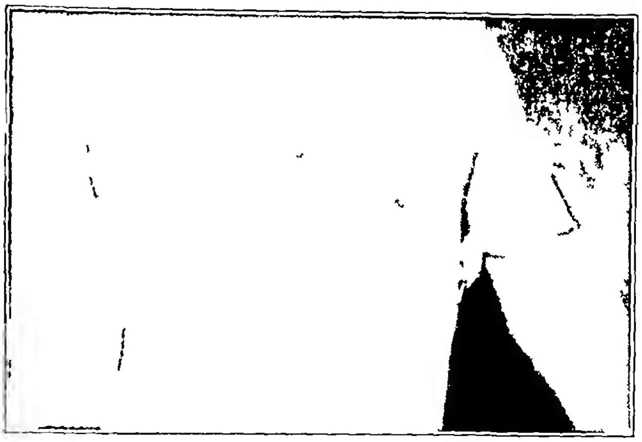

FIG. 8

While still allowing limited motion, the "check rein" prevents excessive abduction of the shoulder after reduction.

In the treatment of simple dislocations, early motion is encouraged. Immobilization by means of a restrictive bandage is purposely avoided. The patient is provided with a sling and is urged to use the arm in all directions, except in abduction and in external rotation. By applying a "figure-of-eight" adhesive strap around the affected arm and the trunk, a "check" ligament is created, and the degree of abduction can be readily controlled (Fig. 8). As healing of the torn structure progresses, a greater degree of abduction may be permitted by gradually increasing the length of this "check" ligament. In this manner, function can be instituted from the very beginning, and the limiting effect of periarthritis can be minimized. Where the dislocation is complicated by a fracture, the beginning of motion must be deferred until consolidation has taken place. This may be accomplished by a Velpeau bandage, a hanging plaster, an abduction splint, or by traction in the recumbent position, as the exigencies of the case indicate.

CONCLUSIONS

During the past ten years, many types of shoulder dislocations, both with and without fracture, have been studied. In all, the treatment here described has been employed. The method has been found easy in its application and gratifying in its results. In no instance could any bone, vascular, or nerve lesion, be attributed to its use. It is founded upon a proper regard for the anatomy of the part, and, in consequence, requires exhibition of only a minimum of "brute force" to achieve satisfactory reduction. In most instances, it can be carried out without the necessity of narcosis. This holds true even for old and infirm patients, provided their confidence has been obtained and is not abused. Because of this, it may be used as an office or Out-Patient Department procedure.

(In an editorial on "Recurrent Dislocation of the Shoulder" in the British Volume of *The Journal of Bone and Joint Surgery* [**30-B**: 6-8, Feb. 1948], particular stress has been laid upon the necessity of preventing external rotation by immobilizing the shoulder in internal rotation for a period of at least four weeks. This seems to be in conformity with a very rational concept of shoulder dislocations, and should be employed in the post-reduction phase of the treatment.)

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DISCUSSION

TRAUMATIC DISLOCATION OF THE HUMERUS

(*Continued from page 172*)

DR JOHN J FAHEY, CHICAGO, ILLINOIS We are indebted to Dr Nicola and to Dr Wilson and Dr McKeever for these important contributions to the subject of shoulder dislocations As previously reported by Dr Nicola, Dr DiCosola and I found that the most constant lesion of experimental dislocation seen at autopsy is a tearing of the capsule from the humeral neck, a portion of the subscapularis tendon sometimes being included We were not able to produce an impacting force, while the extremity was in abduction and external rotation, which we thought was responsible for the shearing of the labrum from the glenoid Abduction and external rotation will produce tears of the labrum from the glenoid or capsular tears from the labrum in approximately 25 per cent of shoulders dislocated at autopsy This same manoeuvre will frequently tear the capsule from the humeral neck on one side and will result in some type of lesion of the labrum on the opposite shoulder

It is not easy to state that the mechanism causing labrum tears in young athletes is different from that in older individuals Younger individuals quickly resume activity, and Dr Nicola's apparatus for preventing abduction and external rotation seems promising in reducing the incidence of recurrence

Immobilization for a period of eight weeks in older patients may result in some type of shoulder disability which outweighs the chance of recurrence

Dr Wilson and Dr McKeever have focused our attention on a very rare type of shoulder lesion Lack of experience with this dislocation does not permit me to discuss this paper thoroughly If we follow these suggestions for early recognition of the cases, our information on this type of dislocation, which has been so clearly demonstrated, should rapidly increase

DR GEORGE E BENNETT, BALTIMORE, MARYLAND I have observed two cases of recurrent posterior dislocation of the shoulder in which reduction could be easily accomplished, but in which the head of the bone would immediately become redislocated posteriorly In both cases, it was found at exploration that the biceps tendon had been partially torn from its sheath and was acting as a bowstring, preventing the shoulder from remaining in position

DR TOUFICK NICOLA (closing) Perhaps the eight-week period that I mentioned would be changed in older patients There is no question in my mind that, if the shoulders in young patients are not immobilized, 100 per cent recurrence will follow the acute dislocation, as happened in our series

The dressing used after reduction allows flexion and extension of the elbow, pronation, supination, and full use of the hand, and yet it does not allow too much atrophy, as would happen if you put it close to the chest

DR JOHN C WILSON (closing) It is believed that the shoulder joint is not stable in external rotation, as suggested by Dr Giannestras Complete internal rotation of the arm, with the forearm behind the back, was the only position which we found to be stable after open or closed reduction of a posterior dislocation of the shoulder This position is not a comfortable one for the patient

Dr Bennett's suggestion of a displaced biceps tendon is most interesting It is easy to understand how such a displacement of the biceps tendon could prevent stable reduction of a posterior dislocation of the shoulder It happened not to be present in the cases under our observation in which the shoulders were opened

Transfixion of the humeral head by means of wires placed through the spine of the scapula has proved to be a satisfactory method of maintaining the reduced humeral head in the glenoid The procedure is simple, the patient is comfortable, and no mechanical difficulties are offered

There are two suggestions to remember in this discussion one is the lateral x-ray in suspected dislocation of the shoulder, and the other is the simplicity of transfixion to maintain the reduction

METASTATIC ADENOCARCINOMA OF THE TALUS FROM THE RECTOSIGMOID REGION

Report of a Case

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Since this presentation is made primarily to report a case of distant bone metastasis from carcinoma of the rectum, a comprehensive review of the literature on this subject is not contemplated; however, some background material is needed. The incidence of metastasis to the skeleton has been variously estimated as from 0.5 to 11.1 per cent. of all cases of rectal carcinoma. Mayo and Schlicke, in their review of 334 cases of carcinoma of the rectum and colon, found that regional or distant metastasis had occurred in 60.5 per cent. of the cases, but that metastasis to bone had occurred in only 1.2 per cent. In an analysis of 366 cases of carcinoma of the lower part of the bowel, Bacon noted metastasis to the skeleton in fifteen cases (4.1 per cent.); in six of these the vertebrae were involved, in two the femur, in two the skull, in two the ribs, in two the shoulder girdle, and in one

FIG. 1

Photomicrograph (× 55) of tissue removed at operation in March 1942, showing adenocarcinoma, Grade 2 (Broders' classification), of the rectum (hematoxylin and eosin stain).

the sternum. All the lesions were osteolytic in character. Turner and Jaffe found, at necropsy, skeletal metastasis in 11.1 per cent. of 1,303 cases of neoplasm of the large bowel. Ghormley and Valls found the incidence of metastasis to bone "from 0.2 to 0.5 per cent of all cases of carcinoma of the gastro-intestinal tract, with the highest incidence of such metastasis in cases of carcinoma of the rectum".

The anatomical pathways involved in the spread of rectal carcinoma are the classical ones,—namely (1) direct extension, (2) the lymph vessels, (3) the blood stream, and (4) transplantation through the peritoneal cavity. Grinnell, in a comprehensive study of seventy-five cases, ably discussed the latter two methods of spread and concluded that distal spread of malignant tumors of the rectum is exceedingly rare and that proximal spread is the rule. Mechling suggested that tumor emboli, entering the thoracic duct from the blood stream, can result in bizarre metastatic lesions. Batson has shown, by his injection experiments in both cadavera and monkeys, that the vertebral veins must be considered as a partial, if not complete, explanation of the manner and route of tumor spread.

In spite of all that has been written on metastatic growth of tumors, not one of the theories explains the scarcity of metastatic lesions below the knees and elbows. It might be conjectured that the more proximal metastatic lesions cause death before evidence of metastasis to an extremity is apparent. With the fact as a basis that metastases to the testes and scrotum are rare and that the temperature of the scrotum is 6 degrees Fahrenheit less than that of the body cavity, it has been postulated that secondary tumor growth below the knees and the elbows is rare because of the decreased temperature of the extremities. Whatever the reason, reports of metastasis to an extremity in cases of carcinoma of the rectum are exceedingly rare. Weston reviewed the literature and found only six cases. He stated that, in 1870, Curling had reported a case of rectal carcinoma with metastasis to the upper part of the radius, and Pitts, in 1891, Aufses, in 1930, Geschickter and Copeland, and Hayden, in 1936, had all reported cases of metastasis to the humerus, in two of which spontaneous fractures were the first symptoms. The sixth case discovered by Weston was also of humeral metastasis, reported by Brown and Warren in 1938.

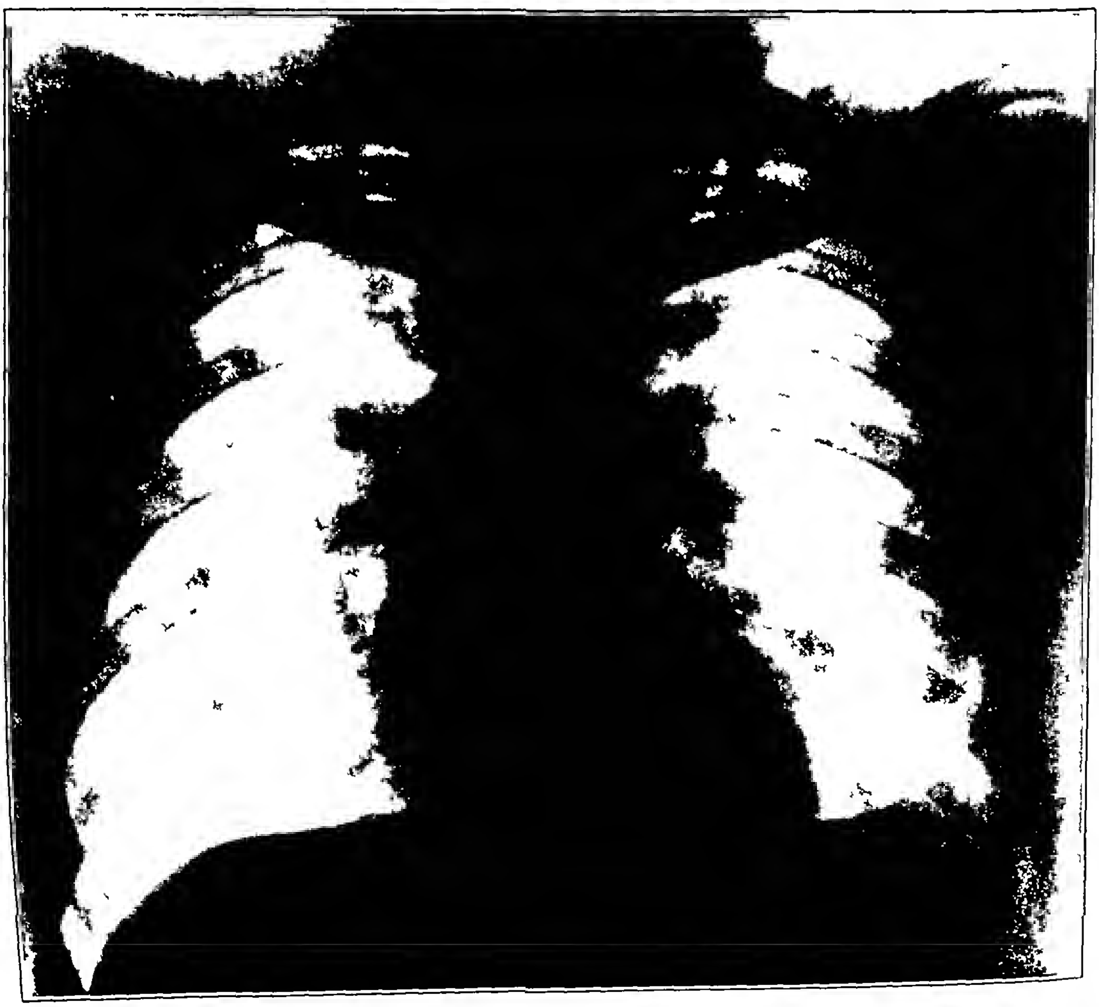

FIG. 2

September 1947. Numerous metastatic lesions in the chest, not unlike inflammatory lesions.

CASE REPORT

A well developed, well-nourished white man thirty-seven years old, came to the Mayo Clinic in March 1942, because he had noted red blood on the surface of his stools for the preceding seven weeks The patient had no other complaints, and was having only slight occasional distress from a duodenal ulcer for which he had received treatment since 1931 He had 13.3 grams of hemoglobin per 100 cubic centimeters of blood, and the red-blood-cell count was 4,810,000 The sedimentation rate was 18 millimeters per hour (Westergren method) Urinalysis and the Kahn test for syphilis gave negative results Roentgenographic examination of the chest revealed nothing of significance, and roentgenoscopic study of the stomach and duodenum after the ingestion of barium was interpreted as indeterminate Proctoscopic examination was carried out to a distance of 24 centimeters, 20 centimeters above the anus a movable lesion was noted, involving the posterior wall Grossly this was diagnosed as a carcinoma Material taken for biopsy at this time was diagnosed in the Pathology Laboratory as adenocarcinoma, Grade 2, of the rectum

On March 28, an anterior resection of 9.5 centimeters of the lower part of the sigmoid colon and rectum was performed and an ulcerating adenocarcinoma, Grade 2, measuring 4 by 3 by 1 centimeters was found (Fig 1) The growth had penetrated the bowel wall, involving the serosa and also the adjacent lymph nodes The surgeon could feel no metastatic lesions in the liver The postoperative course was uneventful except for one period of transient jaundice, and the patient left the Hospital on the thirty-fifth postoperative day

The patient returned to the Clinic at intervals of six months after this operation, and a proctoscopic examination was performed each time In December 1946, the distal 26 centimeters of the bowel was pronounced clear However, in January 1947, the patient returned with a vague history of increased gurgling and activity in the upper middle portion of the abdomen of three months' duration, and of persistent postprandial vomiting and inability, for the past week, to pass a stool without the aid of an enema He had lost a moderate amount of weight He was admitted to the Hospital and a conservative regimen, consisting of the administration of intravenous fluids, a soft diet, and sedation, was instituted He seemed to progress fairly well, but on the tenth day in the Hospital symptoms of obstruction became prominent and an emergency laparotomy was done At operation, hard nodes were felt around the head of the pancreas and in the periaortic region, and at the ligament of Treitz there was a mass which was obstructing the intestine A posterior gastro-enterostomy was done Unfortunately no specimen was removed for biopsy, but the surgeon considered the lesion metastatic

Routine roentgenograms of the chest, in January 1947, showed an area of infiltration at the level of the second anterior interspace, which was thought to be minimal tuberculosis A series of sputum examinations were negative for acid-fast bacilli at this time

Fig 3-A   Fig 3-B

September 1947 Destructive process in the posterior tip of the left talus, suggestive of destructive arthritis with effusion

Fig 4

Photomicrograph (× 55) of specimen removed from the left talus shows the invasion of the bone by adenocarcinoma, Grade 2, of the rectum (hematoxylin and eosin stain)

In July, the patient returned because of intermittent pain and swelling of the left leg and ankle of about four months' duration He had had anorexia and had been losing weight gradually since January Roentgenograms of the left ankle failed to reveal any lesion, but those of the chest showed an increase in size and number of the lesions first noted in January Repeated examinations of sputum were again negative for acid-fast bacilli, although the opinion of the various consultants favored a diagnosis of metastatic malignant lesions rather than tuberculosis Biopsy of material from the ankle was considered, but in view of the fact that some hemoptysis had occurred in the preceding month, biopsy was deferred, and a course of five roentgen treatments was given to the abdomen and left ankle with some relief of pain

On his return in September, the patient complained of continued pain and swelling in his left ankle, which had become severe enough to prevent his bearing weight on the extremity He also complained of easy fatigability, lack of appetite, and gradual loss of weight The lesions in the thorax were still progressing (Fig 2) and his cough and hemoptysis had become more severe Roentgenograms of the left ankle revealed a destructive process of the posterior superior aspect of the talus, which was strongly suggestive of a destructive arthritis with effusion (Figs 3-A and 3-B) The concentration of alkaline phosphatase was 9 7 and that of acid phosphatase was 2 3 King-Armstrong units per 100 cubic centimeters of serum Since it was felt that a biopsy examination of the talus would greatly clarify the interpretation of the condition in the thorax, even though repeated sputum examinations were negative for malignant cells and acid-fast bacilli, a specimen was removed from the talus The pathologist reported adenocarcinoma, Grade 2, with frank rectal tissue present (Fig 4) The patient was given another series of roentgen treatments to the left ankle A letter from his wife, in December 1947, indicated that the patient was in his last illness He died on April 13, 1948

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(*Continued on page 202*)

BILATERAL OSTEOCHONDRITIS DISSECANS OF THE PATELLA

BY SAMUEL KLEINBERG, M.D., NEW YORK, N. Y.

Osteochondritis dissecans of one joint is a fairly common lesion. It is most frequently found in the knee, but occurs also in other joints, especially the elbow, ankle, and hip. A bilateral lesion of the patella, although known, is rare. The case to be reported is the only one seen by the author. There was no history of trauma, and the anatomy of the joints, clinically, roentgenographically, and at operation, revealed no abnormality or anomaly to which the pathological findings could be attributed.

M. H., sixteen years old, was seen on February 1, 1945, because of swelling and occasional pain in the *left* knee. The pain had occurred intermittently for several weeks, the swelling had appeared ten months previously, without any known antecedent injury or illness. This patient was an active boy, indulging in many sports.

The examination revealed moderate enlargement of the left knee with some excess of synovial fluid. There was distinct thickening of the synovial tissue in the suprapatellar area, but no local heat. Motions of the knee were free and there was no abnormal mobility. There was atrophy of the left thigh of one and seven-eighths inches. There was no tenderness to pressure over the patella, the articular surfaces of the femoral condyles, or the menisci. Lateral roentgenograms (Fig. 1) showed an excavation of the middle two fourths of the articular surface of the patella. No loose body was seen, but the diagnosis of osteochondritis dissecans was fairly evident.

On February 13, the knee was exposed through a medial parapatellar incision. A large irregular chondral body lay on the anterior aspect of the articular surface of the femur, directly behind the patella and connected by a slender pedicle to the medial portion of the posterior surface of that bone. Here the articulating cartilage was absent over an area of about one square inch, having been replaced by friable, soft, connective tissue. The replacement tissue was excised, together with the pedicle and loose body. The thickened and congested synovial membrane in the suprapatellar pouch was also excised. The excavated area was curetted.

The pathologist's diagnosis was chondritis (osteochondritis) dissecans of the patella.

In June 1945, while the left knee was still under treatment, the patient complained of discomfort in the *right* knee. The clinical findings and a roentgenographic study (Fig. 2), made on June 20, were negative. A check-up examination on September 19 was also negative, but the boy stated that after sitting for a long while and getting up he had had momentary discomfort on the medial side of the knee. The following night he was awakened by pain and found that his knee had locked. Examination a few hours later revealed a palpable loose body in the suprapatellar area, medial to the patella. The patient stated that he had felt the loose body several times previously, but had not mentioned it.

FIG. 1

FIG. 2

Fig. 1. Lateral view of left knee shows an excavation of the middle two fourths of the articular surface of the patella.

Fig. 2. In lateral view, the right knee is apparently negative and was diagnosed as such originally, but in retrospect there appears to be a slight indentation on the middle of the articular surface of the patella.

On September 24, a large, loose, seemingly osteochondral body was removed from the quadriceps pouch On the lateral portion of the articular surface of the patella was found a crater, from which the loose body had evidently originated There was no other evidence of chondromalacia in the patella or the femur The edges of the crater were beveled and its base was made smooth by curettage

The pathologist's report stated that sections showed the loose body to be essentially cartilaginous The diagnosis was osteochondritis (chondritis) dissecans

The patient was discharged as well on April 19, 1946

A MODIFIED PLASTER-OF-PARIS SPICA JACKET

BY BOYAN HADJISTAMOFF, M D , SOFIA, BULGARIA

From the Surgical Clinic, Sofia University, Sofia

The plaster-of-Paris spica jacket developed by the author is constructed of several plaster slabs The first encircles the iliac crests and the second surrounds the thorax near the axillae, each slab being reinforced by several encircling turns Two vertical slabs go over the shoulders, at each place of crossing they are fastened to the upper horizontal slab by means of two gauze strips, previously inserted under the horizontal slab The vertical slabs are also attached to the horizontal slabs by means of several encircling turns Then the axilla is molded with a small slab (40 centimeters in size) A plaster jacket provided with openings is thus formed, which supports the upper extremity The sixth and last slab is placed along the length of the entire upper extremity The fifth and sixth slabs are supported by encircling turns over the shoulder and around the limb The plaster "slab" spica jacket is completed by the placing of the supporting stick between the anterior superior spine and the forearm, near the wrist joint (Figs 1 and 2)

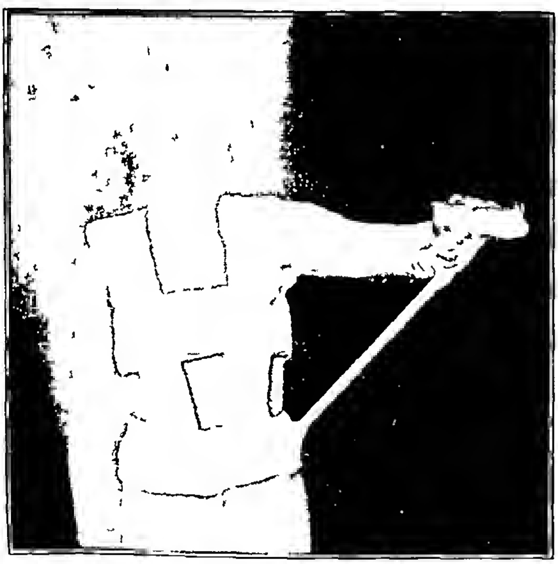

FIG 1

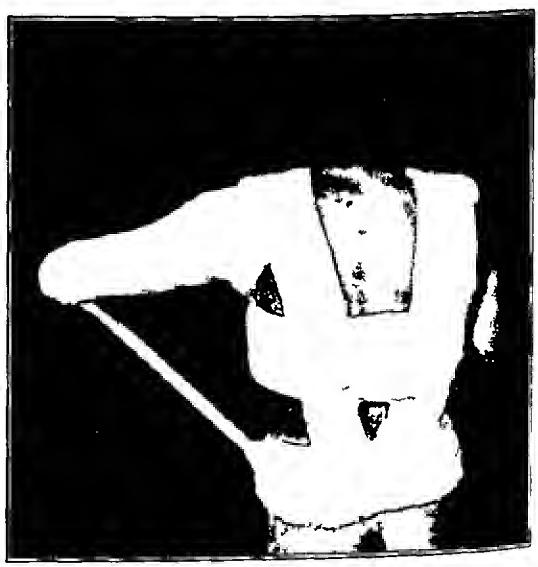

FIG 2

"Slab" jacket applied to patient who had been operated upon for habitual dislocation of the shoulder joint

The technique described makes the plaster-of-Paris spica jacket light and cheap No more than twelve plaster bandages, 8 to 10 centimeters wide, and a comparatively small quantity of cotton, are used With the aid of trained assistants and with previously prepared plaster slabs (rolled like a bandage), the plaster-of-Paris spica jacket can be applied in ten or fifteen minutes The body is well ventilated and can be partially cleaned Breathing is unrestricted

FIBROUS DYSPLASIA

Report of a Case

BY PHILIP T. SCHLESINGER, M.D., GLENS FALLS, NEW YORK, AND SIDNEY KEATS, M.D., AND ANDREW C. RUOFF, III, M.D., ORANGE, NEW JERSEY

From the New Jersey Orthopaedic Hospital, Orange

The purpose of this paper is to record a case of fibrous dysplasia of bone, presenting the unusual complication of massive hemorrhage with absorption of a large section of the tibia.

Jaffe described a case of fibrous dysplasia in which a similar complication had occurred in a rib. Although vascular dilatation and capillary hemorrhage are frequently noted in fibrodysplastic lesions, Jaffe's case is the only one known to have been reported in which massive hemorrhage occurred.

A preoperative diagnosis of sarcoma was made in this case and in Jaffe's case, because of the rapid development of the lesions. In each, extensive pathological study of the lesions which had been removed *in toto* failed to reveal any evidence of malignancy, the changes being ascribed by the pathologist to massive hemorrhage. In the case described here, this complication might have been suspected because, in two previous operations on the patient's femur and tibia, bone bleeding was encountered which was extremely difficult to control.

CASE REPORT

C. S., a white boy, was first seen on May 18, 1937, at the age of five years, with a fracture of the right femur which had occurred two years before and which had failed to unite. The roentgenograms showed generalized osteoporosis and distention of the entire right shaft, characteristic of fibrous dysplasia, and an ununited transverse fracture at the junction of the upper and middle thirds. Roentgenographic changes of a similar nature were seen in the upper third of the shaft of the left femur, and changes characteristic of an early stage were present in the right tibia (Fig. 1) as well as in the left tibia.

On June 4, 1937, an open reduction of the fracture of the right femur was performed. It was noted that the bone was unusually vascular. Fibrous tissue was removed from the site of fracture, and bone grafts were placed. Lateral bowing was corrected manually and a hip spica was applied. On microscopic examination of the specimen, fibrous tissue containing numerous small blood vessels and occasional bone trabeculae was seen, and the diagnosis of fibrous dysplasia was made. On September 22, 1937, there was bony union clinically and by roentgenogram. The spica was removed. Refracture occurred thirty-eight days later, when the patient fell at home. He was again immobilized in a spica for three and one-half months, at the end of which time roentgenograms showed a moderate amount of callus. One month later, on March 13, 1938, he again fractured this bone while lying in bed. At a second operation, March 1938, the cortex was found to be quite thin and broken through. The medullary cavity was filled with fibrous tissue which was extremely vascular and bled profusely wherever disturbed. This was thoroughly curetted for some distance and packed with iliac grafts. After four and one-half months, the fracture was clinically solid, although the roentgenograms showed little callus.

The patient returned January 3, 1939, complaining of pain in the region of the right tibia (Fig. 2); he had fallen while walking with crutches, three days before. On physical examination there was found to be tenderness over the tibia anteriorly, at the junction of the upper and middle thirds. Roentgenographically, there was no evidence of fracture, but considerably more of the bone was involved in the dysplastic process and there was localized rarefaction in the tender area.

On his return, March 27, the mother stated that bowing of the right leg had been noted two weeks before. The roentgenogram taken at that time showed an incomplete fracture line at the junction of the upper and middle thirds. There was lateral and anterior bowing. The entire shaft showed involvement in the pathological process. A hip spica was applied. After seven months, the patient became ambulatory, with a brace supporting his right leg.

Between January 3, 1939, and October 3, 1944, the patient suffered successive pathological fractures of the right ulna, both bones of the right forearm, right femur, right humerus at the lower third, right humerus

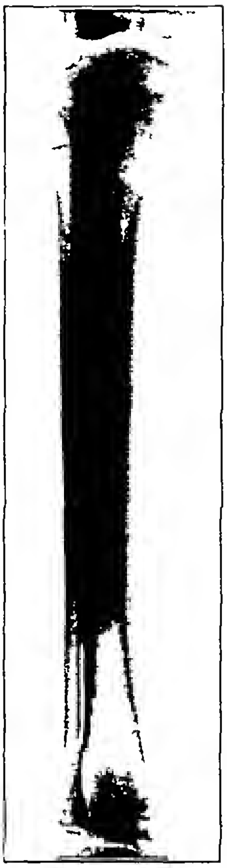

FIG 1

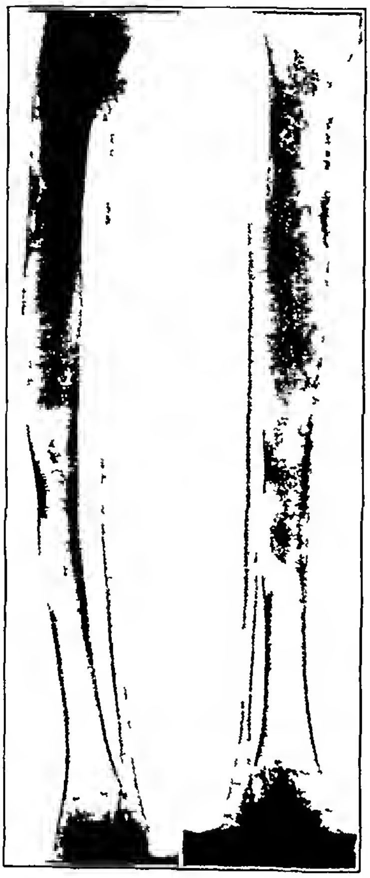

FIG 2

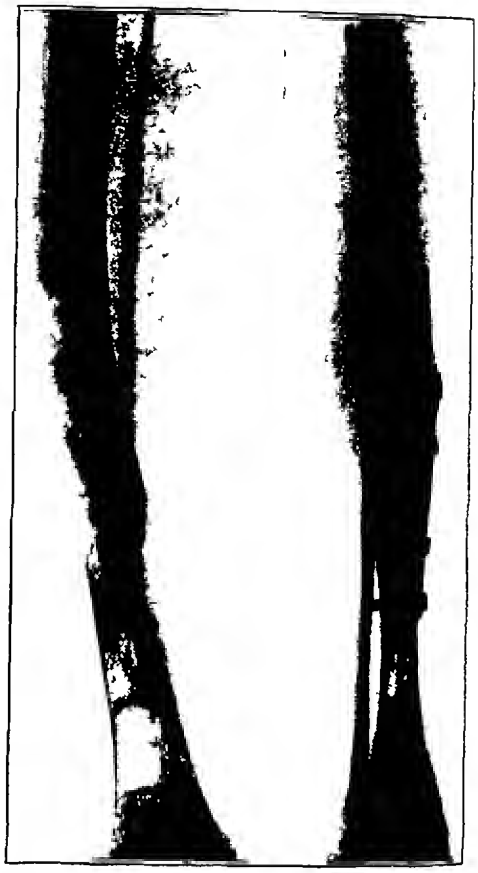

FIG 3

Fig 1 Right leg, May 18, 1937 There is involvement of the middle two quarters of the tibia with slight distention and some areas of rarefaction

Fig 2 Right leg, January 3, 1939 Showing involvement of upper two thirds of the shaft of the tibia with distention and thinning of the cortex and rarefaction Some irregular sclerosis can be seen in the upper portion Slight anterior bowing is present in the lateral view

Fig 3 Right leg, July 23, 1942 Showing healed pathological fracture with the plate and screws *in situ*

at the middle third, and two fractures of the left femur Roentgenograms of these bones showed extensive changes characteristic of fibrous dysplasia

On April 26, 1942, while not wearing his brace, the patient fell and fractured his right tibia This fracture was plated, and a toe-to-groin cast applied Three months later, the fracture of the tibia appeared solidly united, both clinically and by roentgenogram (Fig 3)

The case was reviewed at this point (Fig 4) Because of his many fractures and the extent of the disease, biopsy was performed on October 27, 1944, to obtain material for further pathological study On reflection of the periosteum, very active bone bleeding commenced which was controlled by bone wax A cube of bone, 1 3 centimeters square, was removed at the junction of the upper and middle thirds of the right tibia Massive hemorrhage was encountered, which was controlled only by prolonged direct pressure after implantation of a piece of muscle The wound healed well with no evidence of hematoma Microscopic examination of the biopsy tissue showed evidence that cartilage was replacing much of the osseous tissue Between the bone trabeculae were many large areas of fibrous tissue which appeared mature histologically, and the diagnosis of fibrous dysplasia was again made

The patient next returned on October 15, 1946, with a history of spontaneous swelling over the right shin of three weeks' duration This area had become quite prominent and very tender He had noticed that the bone seemed to drop away from the skin at this point He complained of weakness and anorexia Examination of the right leg showed a prominent diffuse swelling over the anterior aspect of the middle third of the right tibia There was no redness, but increased heat as well as a considerable amount of diffuse tenderness The mass was fairly firm but not hard at any point, and a sensation of crackling could be felt There was definitely abnormal mobility No discoloration was present The patient complained of much pain on motion of the leg Roentgenographically, in the mid-portion of the tibia, there appeared to be complete dissolution of the osseous elements for a distance of 7 centimeters, the normal bony outline being replaced by three large cystic areas There was extreme atrophy of the fibula, only a string-like remnant remaining (Fig 5) The proximal third of the tibia showed an irregular elevation of the periosteum The bone appeared as regularly mottled osseous material, with no trabeculation and no discernible cortex or medulla It was thought

that sarcomatous degeneration had taken place and on October 18, a supracondylar amputation of the right thigh was performed Despite considerable hemorrhage from the end of the femur and soft tissues, healing was uneventful

Microscopic examination of tissue taken from several parts of the amputated specimen failed to reveal evidence of malignancy The microscopic picture revealed not only the characteristic findings of fibrous dysplasia—large areas of mature fibrous tissue interspersed with bone trabeculae, islands of calcified cartilage, and endothelial-lined spaces—but also evidence of fairly recent massive hemorrhage and degeneration of tissue

The following excerpts are from the description of the gross specimen of the tibia (Fig 6) by Henry J Jaffe

"The tibia was exposed by dissecting the soft parts away from it In the middle third of the tibia, on the medial side, a metal plate was found, attached to the bone by four screws, this plate having been inserted at the time of treatment of the pathologic fracture The plate was removed in the course of the dissection There was complete union of the fracture at the site of the plate The fibula was thin and rather tortuous, and was separated away from the tibia The muscles of the leg were extremely atrophic The vessels showed nothing remarkable Specifically, they were examined for bulbous expansions as evidence of neurofibromatosis, but there was no sign of this anywhere

"The tibia was cut in the sagittal plane The cut surface showed that the expanded flail area was the

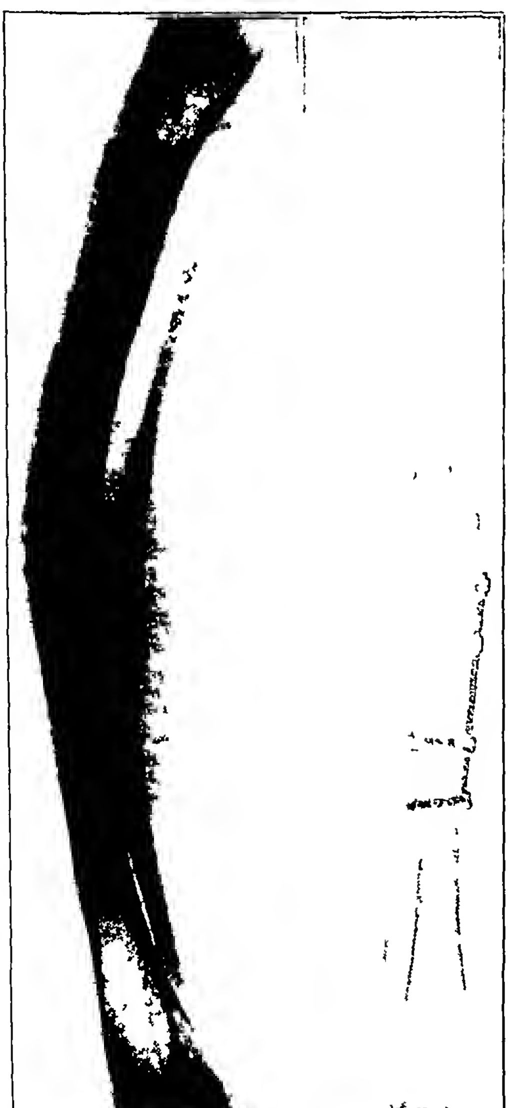

FIG 4

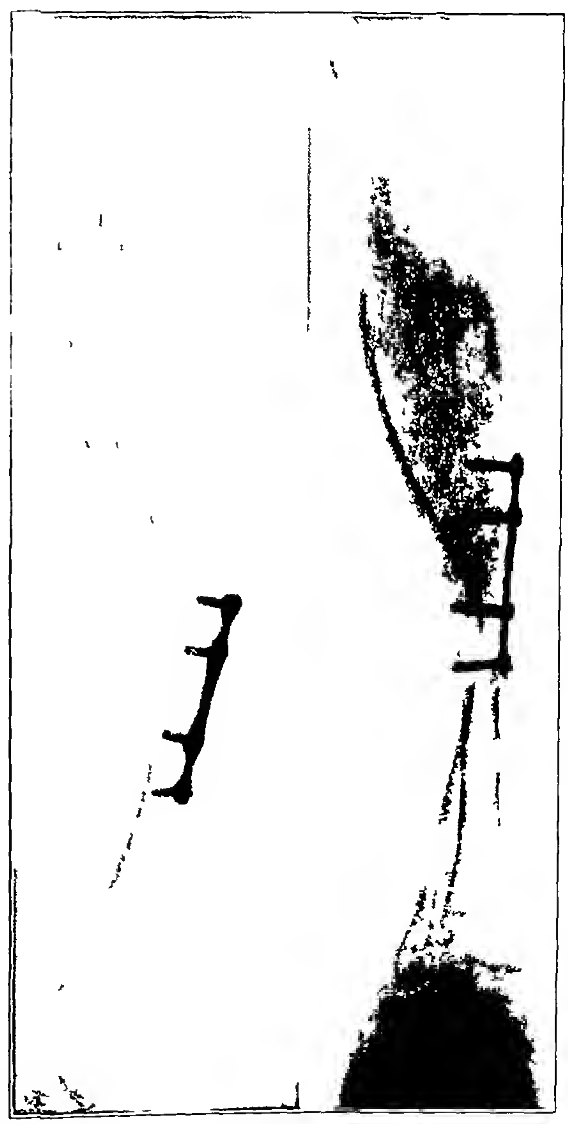

FIG 5

Fig 4 Right leg, October 28, 1944 Showing the characteristic stippling of the late stage

Fig 5 Right leg, October 15, 1946 A large shadow of soft-tissue density can be seen in the mid-portion of the leg The middle quarter of the tibia can be faintly seen in this mass The upper two thirds of the fibula has been reduced to almost string-like size, with a tortuous contour

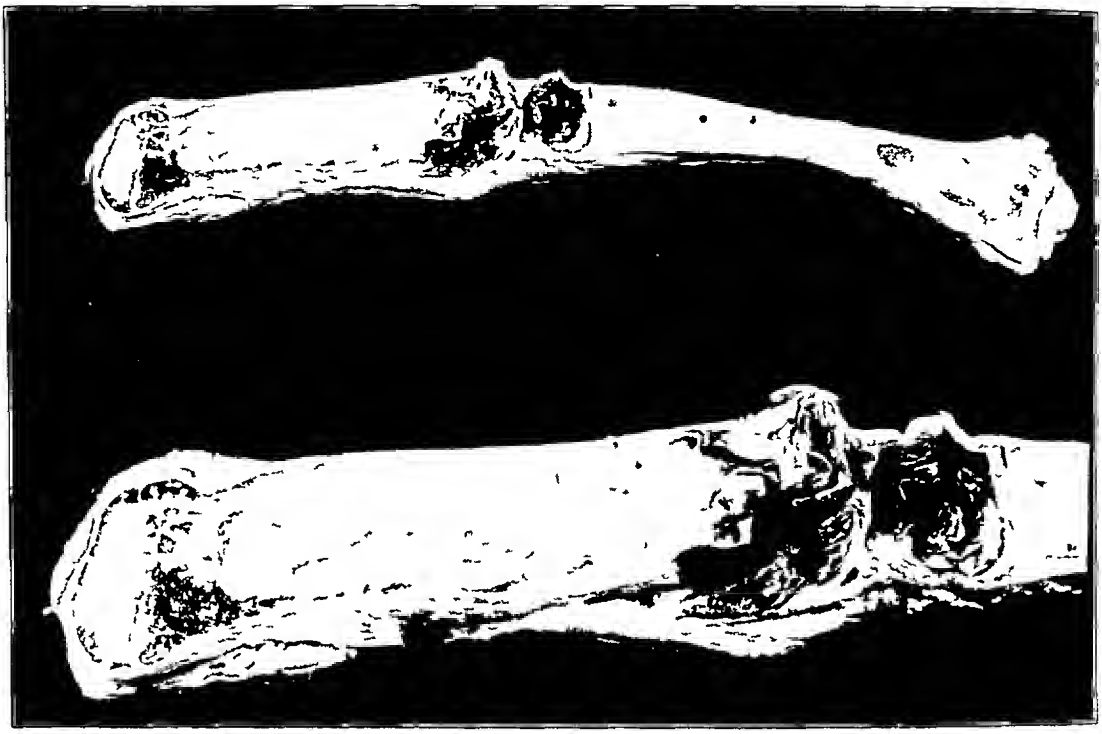

FIG 6

Sagittal section of the right tibia Cyst formation and hemorrhage are seen in the expanded flail area No bone can be seen in the interior in this region The remainder of the shaft consists of pathological tissue, showing compact trabeculae, fibro-osseous tissue, and islands of hyaline cartilage

site of cystification and hemorrhage and that in this area all bone substance was lacking in the interior, th continuity of the upper and lower fragments of the tibia being maintained by the periosteum and, in place by a shell of subperiosteal new bone The cystified area of dehiscence in the tibia measured about 7 cent meters in length, and its lower end began at the level of the uppermost screw, which held the plate again the medial surface of the tibia

"The cut surface also shows that the interior of the tibia, above the dehiscence, is completely obliterate except for about 1 5 centimeters below the upper epiphysial plate The tissue filling the marrow cavity quite osseous and is composed apparently of closely compacted trabeculae of new bone Within the substanc of this new bone there are some small islands of hyaline cartilage and a larger focus of hyaline cartilage present at the upper margin of the obliterating osseous tissue and considerably more cartilage at its low extent The latter cartilage forms the upper border of the hemorrhagic cystic cavity Below the dehiscenc the marrow cavity is obliterated for 5 centimeters by compacted trabeculae of osseous tissue whose fibr osseous nature is more evident in the immediate vicinity of the cyst The lower half of the tibia also show beyond the large obliterating tissue mass, a few smaller scattered areas of osseous tissue, the lowest of whic reaches to the lower plate

"In the sagittal cut surface, the lower epiphysis shows atrophy of the spongiosa but no evidences o fibrous dysplasia However, the upper epiphysis shows a few scattered islands of fibro-osseous tissue in it central region The epiphysial cartilage plates of the tibia in the plane of the section are not particularl remarkable, though, abutting on the metaphysial side of the upper plate, there is a small island of cartilag The cortex of the tibia is thin everywhere, and whatever undiseased spongy bone is present is extremel atrophic "

Laboratory Findings

Except for a somewhat elevated phosphatase level on one occasion, the laboratory tests have bee within normal limits These have included blood counts, bleeding, clotting and prothrombin time, bloo calcium, phosphorus, cholesterol, chloride, and erythrocyte sedimentation rate Urinalysis and blood Was sermann reaction were negative

It should be mentioned that this patient has shown none of the extraskeletal mani festations of Albright's disease The onset of puberty was normal No pigment spots hav been found in the skin

Jaffe, in 1946, discussed a case with development of symptoms similar to those in thi case The patient presented a tumor, the size of a football, in a fibrodysplastic rib Th

rib was resected by Leo Mayer, and a diagnosis was made of sarcomatous degeneration of a fibrodysplastic lesion. The pathological findings were similar to the findings in this case,—that is, there was no evidence of malignancy, the swelling was due to massive hemorrhage.

It would seem, on the basis of these two cases, that the clinical picture of fibrous dysplasia should be broadened to include the complication described here. This complication may be suspected in a patient with fibrous dysplasia, who presents a rapidly expanding bone tumor.

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A TYPE OF EXTENSION APPARATUS*

BY A. VON PETZ, M.D., GYOR, HUNGARY

From the Surgical Division of the Holy Trinity Hospital, Gyor

The apparatus described here has two advantages. First, it can be easily mounted on any operating table, and, second, its extensor action corresponds accurately to the axis of the involved limb.

Since Mathijsen introduced the plaster-of-Paris bandage in the latter half of the nineteenth century, numerous extension devices have been developed to facilitate the application of plaster immobilization dressings. When examined carefully, it is found that almost all fail to exert a pull in the true axis of the limb, because they do not take into account the anatomy of the locomotor apparatus and the differences caused by age and sex. The only striking exceptions are the large orthopaedic tables of Albee, Compere, and Roger Anderson. It would be well for those who devise extension apparatus to accept the advice given by Hippocrates to his son, Thessalus: "Study geometry and arithmetic, if you would gain a better knowledge of the bones."

As is well known, the femora are not parallel to one another; they, together with the tibiae, form a triangle whose base is the width of the pelvis. The width of the base is further increased by the outward inclination of the femoral neck. In women, the base of the triangle is broader than in men. Since almost all extension devices are attached to the perineal bar, it is obvious that the pull is directed, not in the axis of the femur, but at an angle, and that, if the femur has been fractured, the effect of such a pull is to create a valgus deviation of the distal fragment. True axial extension must, of course, have its

* Translated from the German by Leo Mayer, M.D., New York City.

fixed point so placed as to correspond to the tip of the greater trochanter, which represents the upper continuation of the diaphysis of the femur

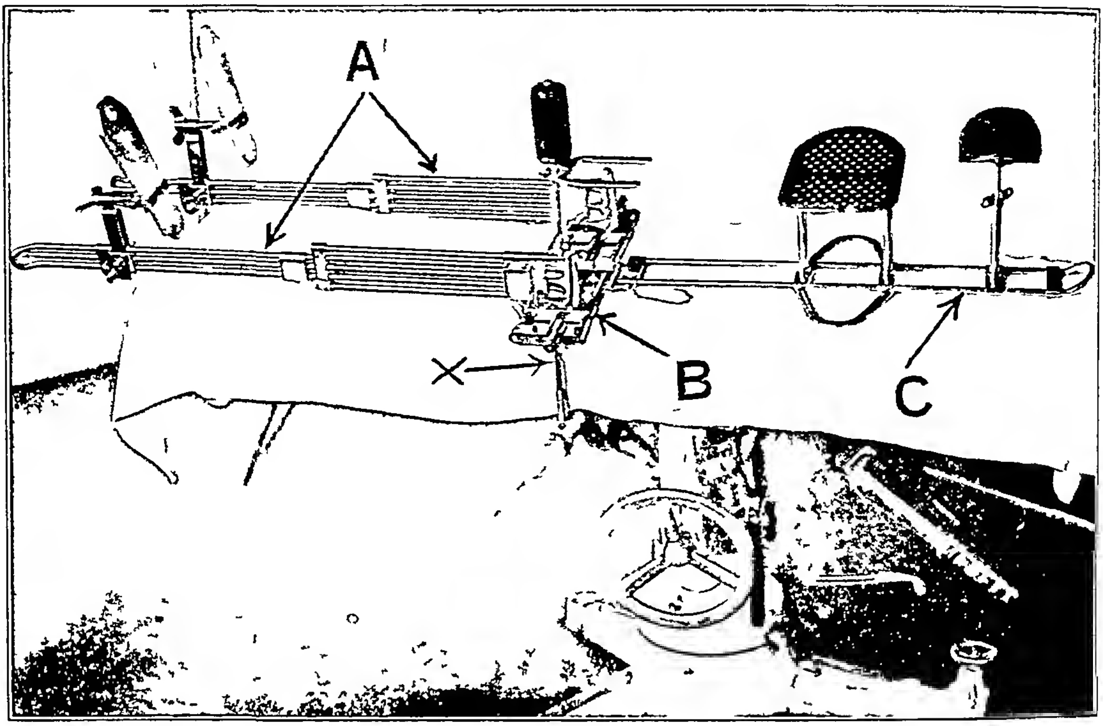

Fig 1

Photograph of the extension apparatus, mounted on an operating table
A Extension bars with adjustable foot plates
B The crossbar, which can be adjusted to correspond to the intertrochanteric measurement of the patient To it is attached a padded perineal bar and a horseshoe-shaped pelvic rest
C Adjustable thoracic and head supports
X Attachment of the apparatus to the table by means of lateral arms, these fit into the clamps which hold the leg supports employed for the lithotomy position

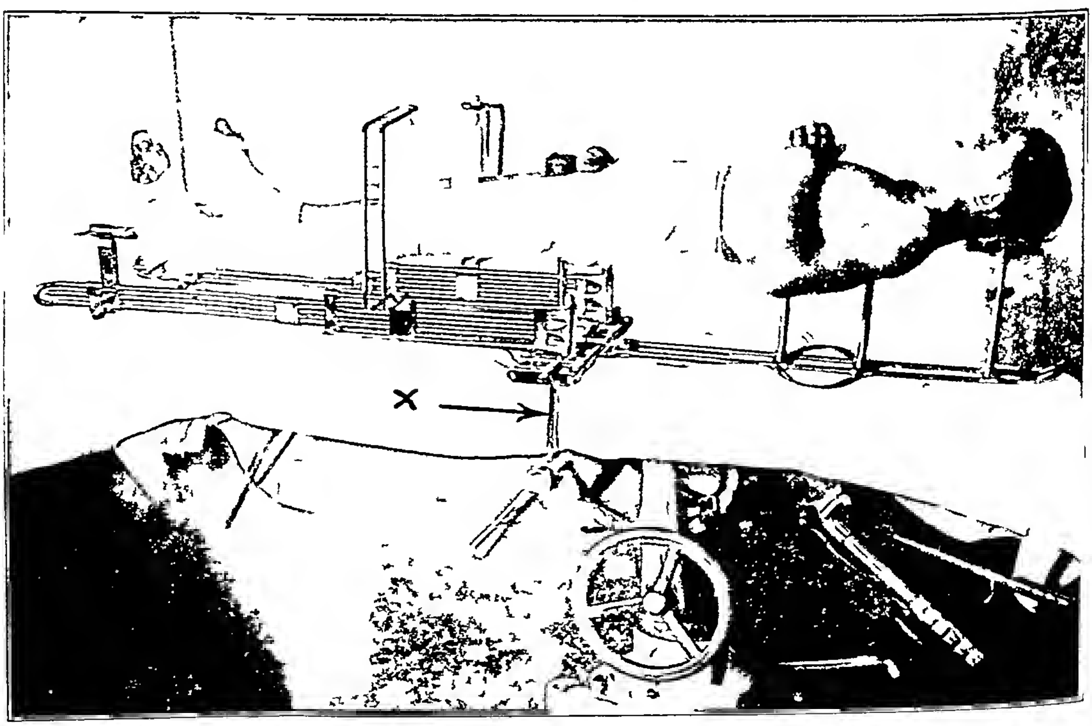

Fig 2

Shows the method of using the suspension frames to prevent sagging of the limbs during the application of plaster-of-Paris spica

The apparatus described here meets these anatomical and geometrical requirements by having the extension apparatus suspended from a broad crossbar, as wide as the average operating table, so constructed as to permit accurate adjustment of the mechanical axis of extension to the anatomical axis The distance between the two trochanters of the patient can be measured, and the extension bars can be placed accordingly The apparatus can be attached bilaterally to any examining or operating table by means of strong clamps (Figs 1 and 2) When not in use, it can be kept in a wooden case The saving of expense and space is obvious

The essential parts of the apparatus are the following

1 Two removable extension bars with adjustable aluminum foot plates

2 The crossbar, provided with a screw device which permits adjustment of the extension bars To the crossbar is attached a horseshoe-shaped pelvic support and a perineal bar On each side it ends in a curved arm, by means of which it can be fastened to the table

3 An adjustable thoracic support and a head piece, both padded with felt, mounted on a light frame

4 Two light removable suspension frames, attached to the extension bars to prevent sagging of the limb

The extension bars are constructed on the same principle as that employed in the author's apparatus for the treatment of tibial fractures[1] They consist of two pairs of parallel 12-millimeter round steel bars, held by two cross-ferrules Between the bars is a screw, controlled by a key When this is turned toward the left, the bars are made to separate, in this way, adequate extension can be secured The position of the foot plates can be adjusted for the individual patient The plates can also be rotated, or turned into a position permitting plantar flexion When plaster is applied, the flat bar supporting the foot plate should not be covered with plaster After the plaster has set, the wing screw holding the plate is loosened, and the plate is withdrawn, this loosens the plate support When this has been removed, a depression is seen in the sole of the plaster, which can be closed with a few turns of bandage The foot plate should be oiled before the plaster is applied, to facilitate its withdrawal Instead of the plate, a hook may be used, to which a Steinmann nail through the calcaneus may be attached

The crossbar can be attached to the operating table by substituting its side arms for the usual leg supports employed for the lithotomy position The crossbar consists of two parallel 14-millimeter round bars, held securely by three transverse ferrules, one in the middle and one on each side In addition there are two movable ferrules, controlled by a screw device similar to that used for extension To these movable ferrules are attached the extension bars, the position of the bars can be adjusted so as to give true axial extension To the middle ferrule is fastened the padded perineal bar and the pelvic rest

The thoracic support is given more stability by an elliptical base which rests on the table The head support can be raised or lowered, and, like the thoracic support, can be shifted cephalad or caudad The frame on which the supports rest is attached to the crossbar by a removable bolt

The suspension frames can be shifted so as to give the limbs adequate support by means of loops of bandage (Fig 2) Axial deviations of the fractured femur can also be corrected by this means After the application of plaster, the loops are easily cut away

When the apparatus is used, whether for the application of plaster or for open operation, it is advisable to cover the frame with towels so as to prevent soiling, particularly of the screw devices

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AMPUTATION FOR TUBERCULOSIS OF JOINTS

A Study of the Therapeutic and Prognostic Value *

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AND WALTER P GRAUL, M D , PHILADELPHIA, PENNSYLVANIA

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This study was undertaken to determine the results from the removal by amputation of a massive focus of tuberculous infection in a major joint The clinical impression at Sea View Hospital has been that amputation offers many patients a longer life expectancy, and that the clinical course improves after such an operation However, many factors must be considered in an analysis of the results of amputation, the authors have attempted to study these factors

A survey of the literature has revealed a marked sparsity of information on this subject Girdlestone [1] has discussed this phase of treatment for tuberculosis of bone and joints in a more satisfactory manner than have others He analyzed nine cases and was satisfied that the results were good in almost all of them In fact, Girdlestone raised the same question which this work aimed to investigate, when he stated "Is it probable that the local lesion is alone responsible for a man's illness and that relief from toxic absorption will enable the man to recover from any other lesion he may have? Or, on the other hand, is the local lesion only active because of the man's general illness, and will any operation be futile or definitely harmful?"

The general indications for amputation at Sea View Hospital during the past ten years have been

1 To remove an extensive focus of infection in the hope of saving the life of a patient, apparently doomed,

2 To remove a focus of infection in a joint destroyed so extensively that it would be impossible to save or fuse the joint,

3 To remove a focus of intractable pain,

4 To remove a deformed hand or foot with multiple draining sinuses and no functional value

All of these indications for amputation may exist in the same patient, or they may exist in any combination

This study includes all patients with tuberculosis of major joints who had amputations at Sea View Hospital from 1937 through 1946 † The only patients excluded were those with amputations of digits, on the basis that such joints do not constitute as extensive a focus of tuberculous infection as do the larger units, and, therefore, the menace to the life of the patient is a relatively minor factor

A total of thirty-five amputations on thirty-four patients were performed during the ten-year period (Table I) Seven of these thirty-four patients are still in the Hospital under treatment and are excluded from all analyses, except those dealing with the location of the lesion requiring amputation

Of the twenty-seven cases reviewed, death occurred in seventeen patients or 63 per cent , the survivors numbered ten or 37 per cent The high incidence of fatalities in this series may be explained by the fact that many of the patients were extremely ill on admission, and died shortly after admission The authors' impression is that removal of a severe secondary focus by amputation has no beneficial effect on the general progress of an asso-

* Read before the Orthopaedic Section, New York Academy of Medicine, April 16, 1948

† Streptomycin was not available during this period

TABLE I

RESULTS OF AMPUTATION IN THIRTY-FOUR PATIENTS WITH TUBERCULOSIS OF JOINTS *

	No of Cases	Sex		Race		Age Range (*Years*)	Average Age	Duration of Joint Lesion		
		Males	Females	White	Negro			Average (*Years*)	Minimum (*Months*)	Maximum (*Years*)
Deaths	17 (63%)	16 (69%)	1 (25%)	8 (57%)	9 (69%)	17–69	42	3	9	5½
Survivals	10 (37%)	7 (31%)	3 (75%)	6 (43%)	4 (31%)	20–62	40	2	6	2½

* Seven patients (six males, one female) still in Hospital

ciated massive pulmonary lesion Such severe pulmonary lesions were invariably the cause of death among these patients In one case, the pulmonary lesion was responsible for death only two weeks after amputation, the operation being performed to relieve the patient of severe intractable pain in the involved joint In over one-half of the cases, death occurred within three months

There is a significant difference in the number of male patients having amputation, as compared with females There were twenty-nine males but only five females,—a ratio of about six to one The reason for this is not clear There are twice as many orthopaedic beds in the Hospital for males as for females The supposition is that the males in this low-income group are more active in the struggle for economic survival than the females, the male is usually the sole support of the family and continues to use his tuberculous joint long after the initial, non-disabling symptoms have appeared, whereas the female is sooner permitted to resort to bed rest, and thus gives the joint a measure of early protection

A further comparison reveals that 69 per cent of the cases in males terminated in death, but only 25 per cent of the cases in females Of the total deaths, 94 per cent were in males, but only 6 per cent were in females

No significant pattern of racial distribution could be found, as there was an almost equal distribution between white and negro patients

The age incidence reveals that children were completely exempt from the necessity for amputation It is, of course, a universal experience that one is able to control joint lesions in children by fusion or cast immobilization far more effectively than in adults The youngest patient in this series was seventeen years of age, the oldest was sixty-nine There was no significant difference in the ages of those who died, as compared with those who survived

A study of the duration of the joint lesion prior to amputation shows that, in those who survived, the lesions had been present for a shorter period of time than in those patients who died (Table I) These, of course, are average figures and could be misleading, but they do show a strong tendency for those with a relatively early lesion to have a better chance for survival The average duration of the joint lesion in those who survived amputa-

TABLE II

LOCATION OF LESIONS REQUIRING AMPUTATION

	Knee		Foot and Ankle		Wrist		Elbow	
	(*No*)	(*Per cent*)	(*No*)	(*Per cent*)	(*No*)	(*Per cent*)	(*No*)	(*Per cent*)
Deaths	9	52	6	55	2	40	1	50
Survivals	4	24	3	27	2	40	1	50
Patients still in Hospital	4	24	2	18	1	20	0	0

TABLE III

MULTIPLE FOCI OF INFECTION

	Location of Other Skeletal Lesions						Patients with Multiple Skeletal Lesions	Patients with Single Skeletal Lesions
	Spine	Sacro-Iliac	Ankle	Sternum	Clavicle	Finger		
Deaths	3	2	4	1	0	1	7	10
Survivals	1	0	0	0	1	0	2	8

tion was two years, whereas the average duration in those patients who died was three years

The location of the lesion which required amputation bears out the well-known fact that the weight-bearing joints are more often and more severely involved than the non-weight-bearing joints Thus, 80 per cent of all the lesions were in weight-bearing joints, such as the knee, ankle, and foot (Table II)

The most conclusive finding in this entire study was the close relationship between the extent of the pulmonary lesion and the eventual outcome At Sea View Hospital, the Gaffky scale is used routinely to indicate the approximate activity of the pulmonary lesion, according to the number of bacilli per microscopic field By the use of this scale as a basis of comparison, the sputum was found to be a remarkably accurate indication of the future death or survival of the patient The patients who died were found almost invariably to have had positive sputa, and usually their sputa had been in the higher range of the Gaffky scale, the average being Gaffky VII, indicating very active and extensive pulmonary involvement Thus, of the seventeen patients who died, thirteen or 76 per cent were Gaffky positive, while only four or 24 per cent were Gaffky negative The findings in those patients who were discharged with arrested lesions were in marked contrast Only one of ten had a positive sputum The count in even this one patient was somewhat doubtful, as the bacilli were found only once in many determinations covering a long period None of the other 90 per cent, at any time during the hospital stay, had a positive sputum

As might be expected, the number of foci in the body had a most important bearing on the end result Thus, every one of the patients who died was found to have at least one other focus besides that existing at the site of amputation Thirty-five per cent had a double focus, consisting of the osseous lesion plus a pulmonary focus, 30 per cent had triple foci, 30 per cent had four foci, and 5 per cent had five or more foci In marked contrast to this, those patients who survived almost never had more than a double focus, and these secondary foci were of a minor character, such as superficial skin lesions and epididymis lesions (Table III)

An attempt was made to study the immediate postoperative improvement following amputation This was difficult, because such an observation would necessarily be based upon the subjective impressions of a constantly changing house staff Therefore, the temperature curves of all these patients before and after amputation were analyzed It was found, in those patients who died, that the temperature curves before and after operation showed no significant change This could be expected, since each of these patients had, in addition to the joint infection, an active, extensive, pulmonary lesion Those patients who survived, however, had no pulmonary lesion, and when the focus of infection in the joint had been removed by amputation, there was immediate improvement and the temperature returned to normal and stayed there

This survey has shown that another indication for amputation may be added to those already given,—namely, amputation as a measure of economy for the patient, a great saving of his time and money That this is worthy of consideration may be seen from a

study of the interval between the time of amputation and the time of discharge from the Hospital In most of the patients this period of hospital stay was extremely short (as little as eighteen days after amputation), most of the patients left the Hospital within three and one-half months In the treatment of such patients, fusion cannot be attempted for many months, or even years The mental well-being of the patient is of the utmost importance, and when he knows that he is rid of his lesion, that there is no chance of a flare-up (at least in that lesion), and that his return to society is probably a permanent one, his morale is greatly improved

In spite of the fact that many of these patients are doomed, by reason of far-advanced, bilateral pulmonary disease, the dramatic relief from severe pain in the bone lesion makes the operation worth while Patients are very grateful for this

The amputation sites were still draining in four of the patients who died One of the survivors required resection of a sinus tract in the stump, ten months after amputation, when last seen, five years later, he was in excellent condition The sites of drainage were not found to be persistent tuberculous foci, although repeated bacteriological examinations were done There was only one case of phantom limb, and this sensation disappeared within two months

This study did not attempt to determine what effect extensive lung resection might have on the eventual outcome of those patients with active chest lesions However, it has become increasingly apparent that the thoracic and orthopaedic surgeons must work in close cooperation The thoracic surgeon is unwilling to operate, unless the patient can be ambulatory the day after operation Thus, the orthopaedic surgeon must provide him with an ambulatory patient as soon as practicable If there is too long a delay, the pulmonary lesion may become inoperable In large tuberculosis centers, this cooperation has proved of the utmost importance to the patient's welfare

CONCLUSIONS

1 Amputation for extensive tuberculous infection of a joint can offer little hope of helping to save the life of a patient if he has an active pulmonary lesion

2 The classical indications for amputation in tuberculosis remain unmodified

3 Males require amputation for tuberculosis more often than do females

4 The best chance for survival exists when the amputation is performed relatively early

5 Amputation of a tuberculous, secondarily infected lesion of a major joint in an otherwise healthy patient allows an early dismissal from the hospital

1 GIRDLESTONE, G R Tuberculosis of Bone and Joint London, Oxford University Press, 1940

A SIMPLE AND EFFECTIVE SPLINT FOR USE IN THE TREATMENT OF CLAWING OF THE TOES

BY WILLIAM J WILSON, M D , WILMINGTON, NORTH CAROLINA

All of us have observed clawing of the toes in patients with low cord lesions and injuries of the lumbar spine These patients usually present some degree of pes cavus as well, but the main complaint is difficulty in obtaining properly fitting shoes, as well as corn formation over the interphalangeal joints The author has tried many different devices, such as beach sandals with straps, to flatten out the toes, but nearly always abrasions of the skin occurred that were slow in healing This tendency to slow healing in such cases also contra-indicates tenotomies or other surgical procedures

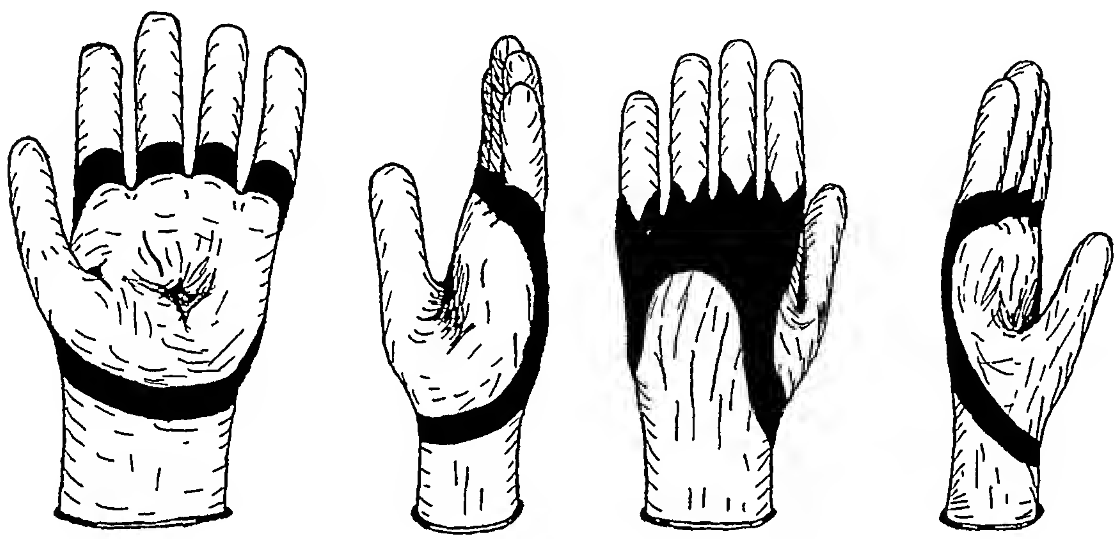

Fig 1

Illustrates how the splint is cut from a rubber glove The palmar, ulnar, dorsal, and radial views, respectively, are shown

Fig 2

Medial, dorsal, and lateral views of foot with splint applied

A simple, efficient, and inexpensive device is presented that has proved to be of great value Not only do the toes straighten, but the patient's walking is improved In one case in which a tumor of the cauda equina was removed, it has been necessary for the patient to wear the device only about half the time to maintain correction In no case has necrosis of the skin or other complication occurred

The splint is made from household rubber gloves, which are easily obtainable from

grocery or department stores Surgical gloves are too thin, and they tend to roll into a cord and cause constriction This does not occur with the heavier household product Figure 1 shows how the splint is cut from the glove Figure 2 illustrates the splint in use The fact that the glove has only four fingers to fit over five toes has not yet offered a problem In one case the band from the fourth finger accommodated both the fourth and fifth toes, but usually when the first four toes are pulled down, the extensor of the fifth toe is sufficiently relaxed

The splint offers the advantages that it can be worn comfortably under the hose in a conventional shoe, and it is not conspicuous

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DEPARTMENTAL TEACHING OF FRACTURES IN THE MEDICAL SCHOOLS OF THE UNITED STATES*

BY HERMAN F JOHNSON, M D, OMAHA, NEBRASKA,
AND SIDNEY L STOVALL, M D, SAN ANTONIO, TEXAS

Within the past decade the management of fractures has gained recognition as a definite phase in the curriculum of the undergraduate students in medical schools throughout the United States The demand for doctors who are adequately trained in the complexities of fracture care has been greatly enhanced by the increasing number of traffic and industrial accidents, as well as by World War II Thus, the study of fracture management is rapidly assuming an importance equal to that of general surgery and medicine

At the meeting of The American Academy of Orthopaedic Surgeons in Chicago, in January 1947, it was suggested by several members of the Committee on Fractures and Traumatic Surgery, then headed by President-Elect Mather Cleveland, that a survey be undertaken of the teaching methods employed in the medical schools of the United States, with regard to fractures and dislocations The Secretary of the Fracture Committee (H F J) was asked by the Chairman to send letters to the medical schools of the United States to determine the number of hours being devoted to this subject, and which staff (general surgery, orthopaedic surgery, or a combination of the two) was held responsible for the teaching Questionnaires were sent to seventy Class A medical schools, the questions asked being as follows

"1 How many hours are allotted to the subject of fractures and dislocations in your medical school?

"2 Are fractures a part of the general surgical service and taught by general surgeons?

"3 On either the orthopaedic or general surgical service are fractures taught by both general surgeons and orthopaedic surgeons or by orthopaedic surgeons alone?"

The response to the questionnaire was surprisingly good, as replies were received from sixty-seven (95 7 per cent) of the schools (Table I) In addition to answering the questions, many of the deans and department heads volunteered suggestions and recommendations, some of which are quoted herein

It is of interest to note the growing trend in the medical schools to ally fracture work with orthopaedic surgery Several years ago fractures, in most instances, were dealt with exclusively by the general surgical service, while today more than half of the recognized schools have correlated fracture care with orthopaedic surgery With this tremendous interest in traumatic surgery, many young men are taking residencies and fellowships in orthopaedic surgery Into many of these same hands the teaching of this subject will ultimately fall, and hence it is to be expected that the growing demand for the placing of this borderline subject in its proper field will become even more pronounced This refers especially to traumatic lesions of the spine and extremities With the sharp tendency to specialization, head injuries and traumata of the chest and abdominal viscera naturally are included among the specialties covering those particular parts of the anatomy With the extensive definitive surgery and corrective measures often necessary in the treatment of skeletal injuries, the orthopaedic surgeon, who has qualified himself for this type of work, should have the opportunity to follow these problems from the time of the emergency care through to the final end result, in many instances this requires several years of observation Too often the early emergency treatment has been rendered by individuals lacking the opportunity to care for these patients subsequently when delayed union, non-union, or malunion develops These patients have then, belatedly, come under the care of the orthopaedic surgeon, who must carry on until the patient has attained his maximum improvement Thus it would appear that, often to the detriment of the patient, the final result has been obtained in many cases in a roundabout manner, rather than by the simple process of placing such cases in the hands of qualified men at the onset

* Report of the Committee on Fractures and Traumatic Surgery, presented to The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 27, 1948 The Chairman of the Committee was Mather Cleveland, M D, and the Secretary was Herman F Johnson, M D

TABLE I

Answers to Questionnaires	Number	Per cent
Total schools	70	100 0
Schools heard from	67	95 7
Fractures treated on orthopaedic service	40	57 1
Fractures treated on general surgical service	27	38 6
Teaching by orthopaedic surgeons	37	52 9
Teaching by general surgeons	9	12 8
Teaching by both orthopaedic and general surgeons	22	31 4

Forty of the schools replying (57 1 per cent) stated that fracture cases were treated on the orthopaedic service, while in twenty-seven instances (38 6 per cent) it was reported that fracture cases constituted a part of the general surgical service The significance of these figures is self-evident when one considers the rapid advances made within this field during the past ten to twelve years It should further be observed that, of the twenty-seven schools designating fracture care as part of the general surgical service, twenty schools divided the cases with the orthopaedic service To illustrate this general trend toward the emergence of fractures as a purely orthopaedic problem, the following notation, taken from the letter received from James R Martin, Professor of Orthopaedic Surgery at the Jefferson Medical College of Philadelphia, seems indicative "Lectures are given by the general surgeons and the practical work by the orthopaedic surgeons Naturally the Orthopaedic Department would like to have the whole problem of fractures placed in their hands Up to five years ago the Orthopaedic Department in our institution had no part in the teaching or practical work of fractures We now treat all the fractures and are teaching the practical side " Thus it is seen that even within the twenty-seven schools adhering to the old method of assigning fracture cases to the general surgical service, the majority have conceded at least half of the fracture service to the orthopaedic department

The Teaching of Fracture Management

It was reported by thirty-seven schools (52 9 per cent) that the instruction of undergraduate students was assigned exclusively to the department of orthopaedic surgery Twenty-two schools (31 4 per cent) reported their teaching to be carried out jointly by the orthopaedic and general surgical departments Only nine schools (12 8 per cent) confined the teaching of fractures to the general surgical department Within this latter group, five schools reported that the general surgeons directing fracture instruction were required to have special qualifications in this field One college anticipated establishing an orthopaedic service, at which time the subject of fractures and dislocations would be turned over to that department entirely

Of the twenty-two institutions in which fracture teaching entailed the efforts of both the general surgical and orthopaedic staffs, six reported an equal division of the work, eight failed to give specific details, one school, the College of Physicians and Surgeons, Columbia University, proposed to have its instructors certified by both the American Board of Surgery and the American Board of Orthopaedic Surgery, six schools stated that the majority of the instruction fell to the orthopaedic department, and one school relegated approximately two-thirds of its instruction to the general surgical service In this regard the remarks of O H Wangensteen, Chief of the Department of Surgery at the University of Minnesota Medical School, seem pertinent "Dr Zierold and I have discussed the general management of the fracture problem from the standpoint of teaching students Dr Zierold is of the impression that teaching is a formal course in fractures, and is not a responsibility that can be divided That is, it should be taught either by the general surgeons or by the orthopaedists "

Within the group of schools delegating fracture instruction to the orthopaedic department, six included fractures and dislocations in the general course of orthopaedic surgery and the subject was in no way segregated

Freshman Instruction Only three schools included the study of fractures and dislocations in the freshman curriculum The University of Louisville Medical School conducts a sixteen-hour course in splinting and first-aid treatment, at the College of Physicians and Surgeons, Columbia University, six hours of clinical work are presented in conjunction with the course in anatomy The patients shown are those evidencing poor anatomical or functional results, in an effort to illustrate to the students the importance of a sound knowledge of anatomy The University of Texas School of Medicine also reported the discussion of fractures in conjunction with the anatomy class, at which time the architectural features of bone are stressed The subject of bone repair is introduced in the freshman year in connection with histology classes In view of these facts, it is to be concluded that consideration of fractures this early in the undergraduate work is deemed inadvisable by the great majority of the schools

Sophomore Instruction Thirteen schools reported the institution of fracture work in the sophomore year The teaching during this period consists primarily of didactic lectures, although one school reported the incorporation of six hours of clinical lectures at the hospital, one school, five hours as assistant in the out-patient

department, and two schools introduce instruction in casting and the use of orthopaedic appliances in conjunction with the sophomore training program. The maximum time allotted to this subject during this phase of undergraduate study is twenty-seven hours, twenty-two hours being engaged in didactic lectures and five hours employed in out-patient work. Of the schools teaching fractures in the sophomore year, the minimum time relegated is one hour. Nine schools devote more than ten hours to the subject, while four schools devote less than ten hours. Fifty-four schools give no consideration to the subject during the sophomore year.

Junior Instruction. During the junior year, the undergraduate students first face the actual problems of fracture treatment in the majority of the medical schools. Seventeen schools reported their teaching programs within this period to include a combination of didactic lectures and clinical activities on the wards, in the operating rooms, and in the out-patient departments. The maximum period of training during the junior year within this group consists of thirty-three hours of didactic instruction and eleven hours of clinical study; the minimum amount of time allotted encompasses four hours of lectures and an unspecified number of clinical hours, covering a period of one quarter, while the average is sixteen didactic hours and twenty clinical hours. Eleven schools restrict fracture instruction in the junior year to a course of didactic lectures, the maximum time allotment within this group being that of the University of Virginia School of Medicine, which specified forty hours of didactic study. The average time commitment was given as approximately sixteen hours and the minimum was represented as ten hours. Four schools reported confining their fracture study to clinical work. As the majority of schools falling within this group did not specify the exact number of hours devoted to the clinical study of fractures, it was rather difficult to make an accurate estimate of the time allotted to fractures. Columbia University requires each junior student to be on call twenty-four hours a day for a period equaling three weeks. The University of Rochester School of Medicine conducts clinical teaching for a period of 110 hours during the junior year.

Senior Instruction. Senior fracture training is comprised primarily of clinical work, the didactic training having been accomplished before this time; however, in some schools the subject of fractures is not introduced until the senior year. Seven schools fall within this latter category. Twelve schools, in addition to the work done in the previous years, continue to present didactic lectures as well as clinical activities. Only three schools which had presented work on fractures in previous years stated that they restricted the senior activities to didactic lectures. Twenty-one schools reported that the fracture study assigned to the senior class consisted entirely of clinical work. Three schools reported that no fracture work of any type was done in the senior year, and nineteen schools failed to comment on the requirements imposed upon the senior students with regard to the study of fractures and dislocations.

Within the first group of schools, the seven introducing fracture work in the senior year, one covers the subject entirely by means of didactic lectures, one confines study of the subject to the fracture work appearing on a general surgical ward during the student's clerkship, and five combine didactic and clinical studies. Twenty-two hours of lectures represent the maximum didactic course, and twelve hours the minimum as well as the average number of hours. The greatest period of time devoted to clinical work is fourteen hours, but as the remaining six schools failed to enumerate accurately their proportionate studies, the average and minimum periods could not be determined.

Within the second group of schools, those continuing combined clinical and didactic studies, the greatest period devoted to didactic lectures is twenty hours, the minimum four hours, and the average approximately twelve hours. The longest period of time relegated to clinical activity comprises forty-eight hours. An average could not be obtained, as no common medium in work estimation had been established.

Within the third group, that of twenty-one schools which restricted senior fracture study to clinical work, the greatest period of time spent in this instruction was reported to be seventy-two hours and the minimum eight hours. Again an average could not be reached, although it was considered to be in the vicinity of eighteen hours.

Comments

In reviewing the comments made by thirty-four of the deans and department heads, a definite impression was gained that the treatment of fractures and dislocations was an ever-expanding field which merited special consideration. This was aptly expressed by H. Bernard, Professor of Orthopaedic Surgery at the University of Colorado School of Medicine, who wrote as follows: "In my opinion *the ideal way would be to have* a fracture service with a qualified orthopaedic surgeon in charge. Or, if a general surgeon were qualified and desirous of teaching, he might be appointed to the fracture service. However, as a rule, a general surgeon cares only about fractures in the medical school up to the point where he has learned as much as he thinks he will on the subject, and then he is willing to release the place to another general surgeon. It would be more efficient and better for the students if those teaching fractures were orthopaedic surgeons, I believe."

In several instances fracture problems and the vast number of fracture cases induced by World War II were mentioned to illustrate the increasing concern with this controversial division of surgery. For example, Acting Dean H. Boyd Wylie, of the University of Maryland School of Medicine, wrote: "We are not entirely satisfied with our present method of teaching fractures and dislocations and are constantly making improvements. With the experience and knowledge of many of our younger men who have returned from military service, and the applications of the knowledge, we believe we are *making good progress*."

have in that broad and solid foundation of undergraduate teaching upon which every practitioner of medicine and its many specialties may build the edifice of his career We should confine our teaching largely to the presentation of basic principles and basic facts, and to training the student in methods of complete and efficient examination of patients The opportunity to teach the student how to use his eyes and his hands in physical examinations is not surpassed in any other field of surgery

It is probably too much to hope that a complete system of undergraduate orthopaedic teaching can be formulated, with which all will entirely agree We are confident, however, that the fundamental principles will emerge clearly in this Conference

THE OBJECTIVES OF UNDERGRADUATE ORTHOPAEDIC TEACHING

BY A R SHANDS, JR, M D, WILMINGTON, DELAWARE

Alfred I du Pont Institute

The teaching of a specialty to an undergraduate student presents one of the greatest challenges in medical education today For the student to become a doctor, he must learn the basic medical sciences and the clinical practice of medicine in the short period of four years The learning of a surgical specialty cannot help but be considered by him to be a minor part of his medical education If, during his undergraduate period, he is not stimulated to acquire a fundamental understanding of a specialty, he will be graduated with a minimum of knowledge as well as with a minor interest in this field of medicine The purpose of this discussion is to present an analysis of the objectives of the teaching of orthopaedic surgery to the undergraduate student, as reported on the questionnaires sent to the seventy four-year medical schools in the United States in 1946 by the Committee on Undergraduate Training, as well as to present the four objectives which the author believes to be the most important

First, an analysis of the answers to Question 8 on the questionnaire sent to the four-year medical school. This question was "State briefly what you consider to be the main objectives in the teaching of orthopaedic surgery to the undergraduate student" Replies were received from the heads of sixty-six orthopaedic departments of these seventy schools In the replies, thirty-two different ideas were expressed The nine objectives mentioned most often, in order of frequency, are as follows

1 The recognition of the more common bone or joint disorders (in thirty-nine replies or 59 per cent) Three of this number mentioned particularly the early recognition of these conditions and two the differential diagnosis

2 The fundamental principles of the treatment of bone and joint disorders (in twenty replies or 30 per cent) Two replies spoke of the mechanical principles of treatment, one of the operative principles of treatment, and three stated that under no circumstances should details of operative or non-operative procedures be given to the undergraduate student

3 The teaching of orthopaedic surgery as related to the general practitioner (in eighteen replies or 27 per cent) Three of this number mentioned an outline of orthopaedic disorders for the general practitioner, six, a sufficient knowledge of orthopaedic surgery for the general practitioner, eight, an ability to refer difficult cases to the orthopaedic specialist, one, the principles of therapy of fractures for the general practitioner, and one, recognition of the orthopaedic conditions for which the general practitioner will be caring

4 The diagnosis and treatment of fractures (in fifteen replies or 23 per cent) Particular reference was made in one each to the teaching of the uncomplicated fracture, the diagnosis of fractures, the immediate treatment of fractures, and the complication of fractures

5 The general management of the more common bone and joint disorders (in fifteen replies or 23 per cent)

6 Teaching of how to perform an orthopaedic examination (in seven replies or 11 per cent)

7 Teaching of the methods of prevention of deformity and disability (in seven replies or 11 per cent)

8 Teaching of orthopaedic and related pathological findings (in seven replies or 11 per cent) Emphasis was placed in some of the replies on teaching a basic knowledge of pathology, and on the correlation of the pathological with the clinical findings

9 The basic knowledge of the musculoskeletal system, particularly the anatomy of bones and joints, and a correlation of this anatomy with the clinical findings (in five replies or 8 per cent)

Other objectives which were mentioned from one to three times were the relationship of orthopaedic surgery to general medicine and surgery, the general scope of orthopaedic surgery, a basic understanding of the field of orthopaedic surgery, an orientation into the problems of orthopaedic surgery, the prognosis of orthopaedic conditions with proper treatment, and the possibilities of their being corrected, how to take orthopaedic histories, a recognition of the normal function of bones and joints, what orthopaedic surgery can accomplish in the preservation and restoration of function, a knowledge of the bacteriology, physiology, and rehabilitation of the orthopaedic patient, making the student conscious of orthopaedic surgery, arousing

in the student an interest in common orthopaedic problems, stimulating the student to further study, office procedures for orthopaedic surgery, and the historical development of orthopaedic surgery

The author believes that the following four objectives for the teaching of orthopaedic surgery to the undergraduate student are the most important, in the order given

The first objective should be to give an accurate knowledge of the scope of orthopaedic surgery Orthopaedic surgery has been defined "as that branch of surgery especially concerned with the preservation and restoration of the functions of the skeletal system, its articulations and associated structures" An interpretation of this definition and all that it implies should be presented clearly to the student

The second objective should be instruction in how to take a satisfactory orthopaedic history and how to perform an adequate orthopaedic examination Instruction should be given in physical diagnosis or the art of performing an examination

The third objective should be a description of the more common bone and joint disorders, presented in such a way that these can be recognized and differentiated from conditions which more rightly belong to other fields of medicine,—that is, the differential diagnosis of the specialty

The fourth objective should be the teaching of the fundamental principles of therapy

As the goal of undergraduate medical education is to train and develop the student into a doctor, with knowledge of all fields of medicine and with the ability to become a good general practitioner and not a specialist, it is the belief of the author that, if these four objectives can be attained in teaching, the student will have sufficient knowledge when he graduates to enable him to screen his patients and to decide what types of conditions he can treat and what types should be referred to the specialist By far the greatest volume of orthopaedic surgery is performed today and always will be performed by the general practitioner, and not by the specialist A careful and thoughtful practitioner, who knows his limitations in specialty practice and when to refer the patient to the specialist, is one of the best assets to the practice of medicine a community can have The aim of the undergraduate medical school is to create this type of physician

The objectives of the teaching of orthopaedic surgery to the undergraduate have not changed since orthopaedic surgery became a specialty, and they are not likely to change However, the techniques of this teaching have changed through the years The audio-visual aids, which now are being used in most medical schools and which will be used more often and more widely as time goes on, enable the teacher to present the subjects more clearly These aids make the learning easier for the student and the attainment of the objectives of teaching more effective

About 1900, Dr Edward H Bradford of Boston, one of the great pioneers and early teachers of orthopaedic surgery, said that orthopaedic surgery is imperfectly understood, few physicians feel competent to practise it, and an objective of the orthopaedic surgeon should be to develop the specialty to the point that the mastery of this particular branch of medicine would be a requisite in the education of every physician Today an objective of undergraduate instruction is not teaching of the student to the point of mastery of this branch, and certainly not to the point of competence to practise the specialty, but the instruction should be given to the point at which the specialty is so well understood by the student that he may feel at his graduation from medical school he has the competence to identify the more common orthopaedic conditions and to know their treatment

DISCUSSION

By Carl E Badgley, M D , Ann Arbor, Michigan

University of Michigan

I am in full accord with the four objectives which have been mentioned, but I think there is a fifth objective which is far greater in importance than all four, that fifth is the stimulus to the student I have purposefully taught orthopaedic surgery with the hope that I would show to the students the possibilities of research and stimulate an investigative interest in medicine

Several years ago, I was invited to give an informal talk in Galveston to the senior medical group at the University of Texas Two distinguished doctors were also on the program They both had excellently prepared scientific papers with lantern slides on investigations in medicine The students, I am sure, were rather bored, yet thought it was part of their prescribed work to sit and listen I am sure, however, they thought that here were two outstanding men who were doing something that they could never do I attempted to show the students that in all probability neither of those men had started out in medicine with the intention of producing the paper which he had just given, but that they had a curiosity for knowledge and for learning which had led them through hardships and difficulties to the final beautiful productions which they had presented

An excellent speech was given recently at a McGill University graduation exercise in which it was said that "knowledge without wisdom, and the will to use it, is sterile"

In conclusion, I would make a plea for this fifth objective and, to my mind, the most all-important of objectives of orthopaedic teaching,—to stimulate in young men the ability to recognize that they have a far better basic background than their teachers had, and a far better potentiality for the development of knowledge in medicine, of which just the surface has been scratched

THE WELL-BALANCED CURRICULUM IN ORTHOPAEDIC SURGERY

By Robert W Johnson, Jr, M D, Baltimore, Maryland

Johns Hopkins University

After hearing Dr Shands' keynote address, amplified as is necessary to get any convention under way and also with the consciousness that I'll be followed by Dr Green, who has a well thought-out and detailed program to offer, I begin to wonder what there is for me to say I have been very lucky in that I have not had to fight for time in which to teach orthopaedic surgery My predecessors at The Hopkins, especially Dr Baer and Dr Bennett, fought and won numerous battles years ago, the first in respect to pure orthopaedic surgery, the latter with respect to fractures and dislocations They won them not because they wanted to teach, but because they could teach and interest the students in their subjects

This brings me to the issue that I particularly wish to stress,—namely, the great difference between teaching of orthopaedic surgery to the undergraduates, or medical students as I prefer to call them, and the postgraduate training of orthopaedic surgeons To undergraduates, we must be doctors, to postgraduates, specialist surgeons If we are specialist surgeons to the undergraduates we are completely out of focus, and our teaching will be blurred and soon forgotten

We must see ourselves and our specialty in relation to medicine as a whole That places upon us the burden of making the student conscious of the neuromuscular-skeletal system as a functioning part of the individual patient as a whole, and not only of explaining to him its normal functions, but of recognizing the abnormalities and diseases affecting this complex system and giving a very brief outline of the principles of treatment of such malfunctioning The realm of orthopaedic surgery literally covers the entire body and brings us into contact with the brain, heart, lungs, endocrines, et cetera As far as undergraduate teaching is concerned, we have the job of integrating our field with all the other fields of medicine, including to no small degree the field of psychiatry

Differential diagnosis, therefore, should be our keynote, using diagnostic methods with special reference to full inspection, gait, posture, mensuration, muscle testing, et cetera These things stimulate the student's thought by giving him means of getting more information for himself than he is apt to get from the usual course in physical diagnosis

How can we best accomplish this purpose of integrating ourselves with general medicine? Let us consider the four years of medical school In the first year, the course in anatomy keeps the neuromuscular-skeletal system before the student, and even the bones are apt to get more attention in this course than they get in later preclinical courses, such as pathology I see no need for orthopaedic surgery to make inroads into the students' time in this year, except for a lecture-demonstration on functional or surgical anatomy, with the idea of showing the student some of the practical implications of his anatomical studies

The second year is the introduction of the student to clinical medicine in most schools I am satisfied in this year with a very short, but I hope sharp, attack on the students in physical diagnosis, giving them gait, posture, deformities, and the secondary effects therefrom Two hours will do An hour or two as a refresher course in anatomy of the surgical type will be useful to those students leaning toward surgery

In the third year, we come to the practical surgery In this year we are expected to deal with the concrete subjects of fractures and dislocations This is the course I am the most uncertain about as it is now organized I think that Hopkins was the first school to delegate this subject of fractures and dislocations to the orthopaedic staff, both in teaching and management

Obviously, ideal teaching should be clinical, but practically it must be didactic in order to cover the subject, with as much clinical material included as possible Somehow, fractures of the femur seem to occur only in the weeks that we have to deal with Colles's fractures, and vice versa We are still fumbling with the problem, but despite the difficulties, Dr George Eaton is doing a good job in seeing that even the embryo gastro-enterologist knows how to recognize and treat the fracture on the spot

Sixteen required lecture-demonstrations, plus voluntary attendance at the weekly fracture clinic and a sort of obstetrical call service for acute fractures in the accident room, comprise this course

We also supply a consultant to the medical-surgical diagnostic clinic, through which all new patients pass and thus come in contact with the third-year student in the general diagnostic work-up

The fourth year is the year of refinement and polish Here we have a twofold program The first part consists of sixteen lectures in a systematic presentation of major orthopaedic subjects—poliomyelitis,

tuberculosis, scoliosis, arthritis, et cetera—which are allocated to various members of the staff with the idea that each will present his special interest and enthusiasm to the student more fully than I could I believe that this has a stimulating effect on both the students and the staff

In addition, there are weekly ward rounds with the small groups of students in their surgical quarter, and this means eight hours for the students and covers about twenty or thirty cases of all kinds from the wards and the Children's Hospital School Stress here is on differential diagnosis, integration of orthopaedic findings with the laboratories, the other surgical specialties, medicine in general, psychiatry, and biochemistry Splinting after-care, occupational therapy, and physical therapy are stressed more than surgical procedures, although principles of surgical approach are discussed Attendance at operations is voluntary

This, briefly, is our set-up and the philosophy behind it first to keep before the student the neuromusculai-skeletal system as an important part of the patient he is going to treat, second, to perfect the student in observation and examination, third, to give him some additional skill in differential diagnosis, fourth, to acquaint him with the possibilities of treatment, conservative and operative, of such orthopaedic problems as he may encounter in his career as a physician, surgeon, or investigator, and fifth, to interest the exceptional student in an orthopaedic career

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THE WELL-BALANCED CURRICULUM IN ORTHOPAEDIC SURGERY

BY WILLIAM T GREEN, M D, BOSTON, MASSACHUSETTS

Harvard University

When we as orthopaedic surgeons face the problem of a balanced curriculum, we are likely to be biased as to the importance of orthopaedic surgery in undergraduate teaching and the amount of time which should be allotted to it However, it is quite obvious to all of us that in many schools, at least, orthopaedic surgery does not receive its due In most schools, a representative of the department of orthopaedic surgery does not serve on the curriculum committee, nor does he have any voice in the final decisions of this committee Often to those serving in such a position, orthopaedic surgery represents a specialty of very limited nature, and it is awarded the same amount of time as is given to a specialty limited in scope and confined to one small anatomical area My remarks are made with the understanding that orthopaedic surgery is a major branch of surgery and that the problems in this field are some of the most common in medical practice Orthopaedic surgery has ramifications extending into all branches of medicine and surgery, and much of its special knowledge is pertinent to the balanced education of a medical student By its nature, orthopaedic surgery lends itself to the teaching of general surgical principles better than do most divisions of surgery It is well to comment here that the purpose of undergraduate teaching in orthopaedic surgery is not to produce orthopaedic surgeons, but rather to teach those basic principles which are essential to a balanced education

It seems to me that somewhere between 20 and 25 per cent of the teaching time in surgery should be assigned to the department of orthopaedic surgery If this means an increase in the amount of time devoted to orthopaedic surgery in an existing schedule; the additional time would not necessarily come from that allotted to teaching in general surgery It might come from various adjustments Furthermore, if the department of general surgery teaches things which ordinarily should be under the department of orthopaedic surgery, such as fractures and bone tumors, the instructional time assigned to orthopaedic surgery may be reduced proportionately Such instruction should, however, be carefully correlated with the teaching in the orthopaedic department

One of the main difficulties, other than that too little time is allotted to orthopaedic surgery, is that it is frequently worked into the curriculum in haphazard fashion, so that it is impossible to develop a reasonable integration either vertically or horizontally Frequently lectures in the clinical years are scheduled without regard to the time of sectional instruction This greatly decreases their value In our experience, students arrive for their assignment to the Department of Orthopaedic Surgery in the third year with little background leading to its understanding The time to start the teaching of orthopaedic surgery is in the first year The head of the department should see that the courses in basic science present that material which is pertinent to future understanding of the specialty Furthermore, the Department of Orthopaedic Surgery should itself take part in first-year and second-year teaching, which should be correlated with the instruction given in the departments of basic science

I should like to present a sample curriculum, merely to consider general principles so that we have something specific to discuss. The details of curriculum must be modified to meet local circumstances

The First Year

In the first year, instruction by the department of orthopaedic surgery should be correlated with the work in anatomy and physiology Six or seven lectures may be given, as follows

1 General musculoskeletal system, body mechanics
2 The trunk and neck, the back

3 and 4 Upper extremities
5 and 6 Lower extremities, gait
7 Abnormalities in embryological development, bone growth

All of these lectures, and they should be well illustrated, should stress normal musculoskeletal mechanisms which, in their presentation, may be emphasized by illustrations of abnormal states Visits of the orthopaedic surgeon with the students in the dissection room at appropriate times is also most helpful

The Second Year

If pathology has been taught in the first semester of the second year, it is desirable to have a schedule of orthopaedic exercises in the second half year These should be designed to acquaint the student with a basic concept of abnormalities of the musculoskeletal system and to show him patients with these problem Ten lectures, appropriately illustrated, might be given during this second year and might be listed as follow

1 The problems arising in the musculoskeletal system, examination of a patient
2 The trauma of bones
3 Infections of bones
4 Joint phenomena, infection, trauma, tendons, bursae, and tendon sheaths
5 Abnormalities of growth, tumors
6 Paralysis
7 Developmental and congenital diseases and abnormalities
8 Mechanical abnormalities
9 Metabolic disease (probably by division of medicine)
10 Therapeutic measures, general, in relation to pathological processes, traction, casts, exercises, et cetera.

In addition to these lectures, there should be sectional work in physical diagnosis of the musculoskeletal system, taught by an orthopaedic surgeon These sections should not contain more than six students for certain of the activities, but the sectional work may well be combined with demonstrations in larger groups, if it is feasible and can be correlated as to time There should be approximately four exercises,—that is, four mornings of sectional instruction in relatively close continuity, occupying a total of twelve hours In addition to these exercises, it is highly desirable to arrange for a single visit of each section for two to three hours to the orthopaedic out-patient department to illustrate the problems that arise This visit should be supervised by an instructor, as should another morning exercise at which the section should make ward rounds to see the problems that are represented and the techniques of treatment Another exercise may well be instruction in basic first-aid, bandaging, and other details, if they are not otherwise covered in the curriculum In all, then, we have had nine or ten lectures of one hour each, and six morning sectional periods of three hours each, totaling eighteen hours of sectional work and ten hours of lecture

The Third Year

This is the time when the students become more intimately acquainted with the patient, with orthopaedic surgery, and with the problems of the musculoskeletal system The purpose is not to teach orthopaedic surgery as a specialty, but to give an understanding of the musculoskeletal system in its relation to the patient as a whole, which is applicable to medicine in general

The third year should emphasize sectional work with patients, but some teaching can well be performed in large groups, particularly with visual aids There is much to be said for and against the lecture including whole classes at this time Such a lecture is likely to be delivered by a stimulating, capable individual, whereas, if all the teaching is done in small sectional groups, there is constant repetition, requiring a great extravagance of instructors' time The result is that the teachers for such groups are not so stimulating or effective as those who might give a lecture to a larger group A good portion of the work must be sectional, but part can be well covered in lectures The difficulty of lectures to a large group is that they are likely to be entirely independent of the sectional work as to time This is not good The ideal would be to present the subjects, well illustrated and in lecture form, to the whole group and to correlate the sectional work with it, this is usually impossible A good compromise is to have sections of moderate size, perhaps a fifth or a sixth of the class for certain of the exercises amounting to lectures and demonstrations, and smaller subdivisions of approximately six students assigned to each instructor for work with patients How this can be arranged depends upon the local environment Translated into detail, there could well be about twenty lectures or exercises corresponding to lectures These should be as intimate as can be evolved These lectures might be tentatively listed as follows

1 The patient and the musculoskeletal system
2 and 3 Congenital anomalies (specific problems, congenital hip disorders, club-foot, other anomalies)
4 Developmental diseases (miscellaneous, coxa plana, slipped epiphysis, et cetera)
5, 6, and 7 Neuromuscular abnormalities, including poliomyelitis, obstetrical paralysis, cerebral palsy, et cetera
8 and 9 The joints arthritis, trauma, other conditions

10 Specific infection of bone,—osteomyelitis, tuberculosis
11 and 12 The back the spine, including cervical spine, mechanical difficulties, back pain, sciatica, scoliosis
13 Tumors and related abnormalities
14 Upper extremity, general
15 Lower extremity, hips to knees inclusive
16 Leg and foot
17 Fractures general management, simple, compound
18 Fractures, upper extremity
19 Fractures, spine
20 and 21 Fractures, lower extremity

Correlated with these lectures, as mentioned, should be sectional work involving time on the wards and in the out-patient department The student should have a chance to work with patients in small groups with adequate supervision, assistance, and independence This sectional assignment should approximate four weeks and should certainly not be less than three weeks

The Fourth Year

In our experience this has been planned in correlation with general surgery, when the students have their long sectional assignment in this field If four months are assigned to surgery, the student's total time in orthopaedic surgery, including fractures, should be not less than two weeks Depending upon the local situation, this can be arranged by assigning the students to the orthopaedic department for two weeks, allowing the students so assigned to make the major teaching rounds on the general surgical service during this period, if possible Likewise all the students in the large surgical section should make regular teaching rounds with the orthopaedic service, perhaps once a week If cases on the two services are in the same wards, the cases on the orthopaedic service may be assigned to the students in rotation, and the work in orthopaedic surgery may go on synchronously with that in general surgery The students should be responsible for the work-up of patients, they should "scrub up" for the operations on their assigned cases, and participate in all the activities affecting these patients In addition, it is our belief that one month of elective orthopaedic surgery should be offered in the fourth year, during which a student may have an opportunity to work with the department, performing many of the duties of a junior house officer

It has not been our purpose to outline these details with the idea that they should be followed, but merely to represent a pattern of instruction and to emphasize that the teaching of orthopaedic surgery should start in the first year and should be gradually woven into the fabric of the curriculum

The object should not be merely to teach the facts in orthopaedic surgery, but to give the student a thoughtful approach to the problems of the musculoskeletal system and to medicine in general It should be mentioned that the allotment of sufficient time does not of itself assure good teaching in orthopaedic surgery The more efficient the teaching, the less time is needed The student's time must be well occupied

DISCUSSION

By Carl E Badgley, M D , Ann Arbor, Michigan

University of Michigan

Our program at the University of Michigan is somewhat similar to that which Dr Green has just outlined

Constantly throughout the year we have clinical conferences with the Department of Anatomy on embryology, attempting to demonstrate the embryological facts which are brought to light in our clinical material We similarly have conferences and clinics in the Department of Anatomy, in which we attempt to demonstrate the need of knowledge of anatomy in clinical material In the second year we have six hours on the pathology of the healing of fractures Also in that second year, with the Department of Internal Medicine, we have six hours in the teaching of physical diagnosis

In the third year the class is divided into sections Each section spends three afternoons a week, for two weeks, in the orthopaedic Out-Patient Clinic Fractures are taught to each section didactically, two hours a week for four weeks We believe that these students acquire a fundamental basis of the knowledge of fractures We have ten orthopaedic lectures In those ten hours we do not pretend to teach all of orthopaedic surgery, but it is our aim to present a knowledge of such topics as bone growth and bone repair, the normal development of the growing child, and the diseases to which that child can fall heir We also present those diseases in adults which are peculiar to our specialty We attempt as much as possible to demonstrate that the work of the Department of Orthopaedic Surgery must be correlated with that of other departments

In the fourth year, as Dr Green recommended, we have the senior medical students with us for the entire time for two weeks During that period of time, they are in the operating room, where they "scrub up" for operations on cases, in the Out-Patient Department, and acting as assistants and clinical clerks in t

wards Once a week we have a general conference on fractures, which the senior residents attend This conference is primarily for the Division of Orthopaedic Surgery, which is in charge of fractures These conferences are also attended by the general surgeons

I would say that, with few exceptions, we have everything Dr Green has recommended for the orthopaedic curriculum

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THE RELATIONSHIP OF THE DIVISION OF ORTHOPAEDIC SURGERY WITH THE OTHER DIVISIONS OF SURGERY

By Alan D Smith, M D, New York, N Y

Columbia University

This morning in his Presidential Address, Dr Robert I Harris said most of the things I had thought of saying on this subject, but stated them very much better than I can

In order to orient ourselves about the position of the department of orthopaedic surgery, we should think of the recent developments of surgery and the fact that there really no longer exists such a department as general surgery We all have to be surgeons first and specialists afterward When I was an intern on the surgical service, thirty years ago, we did abdominal and thoracic surgery, and brain surgery, we treated fractures, we practised gynecology and urology, and we were really general surgeons That is all changed Technical advances in surgery have been so great that no one now thinks he can master all those techniques, and he has been forced to specialize more or less in one particular field of surgery By general surgery, I think we mean the fundamental principles of surgery which we all have to master to be surgeons The idea that it is necessary for men to learn the principles of treatment of shock and water balance, infection, and so on, by going through the department of general surgery (which now is really the department of visceral surgery), is no longer true

Therefore, I think that the department of orthopaedic surgery should be simply one of the departments of surgery, but a very important one If you think back, you will see that until a comparatively short time ago, what we now consider as the scope of orthopaedic surgery was almost the entire field of surgery, before abdominal and thoracic surgery came into being We really cover a great part of the body and treat more types of lesions than any other branch of surgery I believe that the best plan is to give each department of surgery a large degree of independence, and yet hold these departments together by an organization, otherwise there will be more or less anarchy

There must be an executive officer of the department You can call him the professor of surgery, if you like, or he may be the professor of visceral surgery, or the professor of orthopaedic surgery or neurosurgery, but he is the executive officer of the department and the one who binds all the different parts together It takes a number of qualities to make a good professor of surgery He has to be a good teacher, a good surgeon, and a good administrator Very often the departments of surgery suffer because the head of the department is not a good administrator, and I think, therefore, that the man should be selected not as much because of the particular field of surgery in which he happens to be interested, but because of these other qualities that are so necessary in administering the department

At Columbia University, all the specialties in surgery are independent, but we have, of course, a professor of surgery I think that is the way it should be done, but the so-called surgical specialties should not necessarily be subordinated always to the so-called department of general surgery There must be a great deal of cooperation between the various branches of surgery, because even in the cases which we consider to belong to the field of orthopaedic surgery we frequently need the special skill of other men, such as the neurological surgeons and plastic surgeons, and we should feel free to call upon them to help with particular problems

Also in teaching there is a great opportunity to collect many of these things and present them as a whole, because you cannot separate diseases into compartments They do not lend themselves to that at all I think that the plan of holding symposia on tuberculosis, for instance, in which the internist, the orthopaedic surgeon, the pathologist, the bacteriologist, and others cooperate to present that disease as a whole, is an excellent one That plan could be extended to other diseases, such as poliomyelitis and cerebral palsy

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THE RELATIONSHIP OF THE DIVISION OF ORTHOPAEDIC SURGERY WITH THE OTHER DIVISIONS OF SURGERY

By Donald King, M D, San Francisco, California

Stanford University

I am afraid that everything I had thought of saying has already been mentioned, and perhaps in a way far better than I could have said it to you I would like, however, to stress one technical method of teaching

which Alan Smith spoke about There has never been *any radical* separation between the various specialties in the Department of Surgery of Stanford Medical School In fact, one might say that this is also true of the various departments For example, all members of the staff attend Dr Bloomfield's Friday morning medical rounds and Dr Newell's Monday afternoon X-ray Conferences, Dr Newell being our Professor of Radiology

During the past two or three years we have been experimenting with a method of teaching which has still further unified the divisions of surgery into a more compact department This method, which is actually a very old one, is used particularly to present those subjects which are of interest not only to the orthopaedic surgeon, but also to other divisions or departments We might, for the purpose of illustration, mention the subject of tumors

A class is conducted jointly by the orthopaedic surgeon, the pathologist, and the roentgenologist Patients are shown to illustrate the various types of bone tumors, and for the benefit of the students, the three professors participate in the discussion concerning each case

Other orthopaedic subjects lend themselves very naturally to this method of presentation I might speak of poliomyelitis, which Dr Smith has already mentioned In presenting this subject, Dr Faber, the Professor of Pediatrics, starts with the presentation of the clinical picture and the acute phases of the disease He is followed by Dr Northway, Professor of Physical Medicine, who demonstrates the physiotherapeutic aspects of the subject Finally, a member of the Orthopaedic Division closes with a presentation of the fundamental principles of the orthopaedic treatment of the disease

Another subject which is well adapted to this method of presentation is fracture of the spine with damage to the cord, where we are able to have the genito-urinary surgeon, the neurosurgeon, and the orthopaedic surgeon participating in the discussion in front of the students in a round-table type of discussion It is quite obvious that such a teaching program requires considerable preliminary preparation and a willingness on the part of various teachers to admit that their particular role is not necessarily the stellar one We've found students to be most enthusiastic about this method of teaching, and I feel that it has resulted in a much warmer interdepartmental relationship than previously existed in our school

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THE USE OF AUDIO-VISUAL AIDS IN TEACHING

By Fremont A Chandler, M D, Chicago, Illinois

University of Illinois

The subject of orthopaedic surgery lends itself admirably to the use of visual aids in its presentation to medical students, especially those in the preclinical years of their teaching Patients are the ideal form of presentation from the visual angle, but they are not always available at the proper time, and some such presentation must be supplemented by other means, such as drawings, charts, models, lantern slides, or motion pictures The need for such aids is brought out in the study of answers to a questionnaire sent out by Dr Shands over a year ago To the question, "Are visual aids, such as lantern slides, motion pictures, models, et cetera, made use of?", seventeen schools replied that they were used extensively, thirty-eight schools replied that their use was moderate, and fifteen replied that they were used only occasionally

To the question, "Would your department be willing to collaborate on such visual aids for teaching if a central office of exchange were established?", sixty-eight of the seventy schools responded in the affirmative This is evidence of the need for such means of presenting the subject of orthopaedic surgery to students

Under the present plan, each medical school attempts to supply these needs through its own departments of art, photography, et cetera This means that seventy medical schools must have seventy artists, often working on the same problem Would it not be possible for us to combine our efforts and share the products of our art departments with one another, supplementing the material which each of us has available with the choice and more selected material which our colleagues have encountered elsewhere, by putting all into a common pool? The effort of preparation would be minimized and many valuable presentations would become available to all

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THE USE OF AUDIO-VISUAL AIDS IN TEACHING

By Joseph S Barr, M D, Boston, Massachusetts

Harvard University

I should like to make clear at the outset that my remarks represent my personal feelings rather than the attitudes of Harvard University

The "chalk talk" is the simplest example of audio-visual education Roentgenograms, dissected specimens, the articulated skeleton, et cetera, may be used as visual material, but such material can be see

satisfactorily by only a handful of students at one time To overcome this, as seen in our scientific sessions, the visual image is enlarged by projection from lantern slides or by making a "blown-up" three-dimensional model of the original I suppose that at present all but a minor fraction of undergraduate or orthopaedic teaching is done with no more complex aids than those just mentioned Many of us have made motion-picture films of operative procedures of interesting cases, but such films, in my opinion, have little or no place in undergraduate teaching There does seem to be a place for a few well-made basic films on orthopaedic subjects

If such films were available, they would improve the general quality of our teaching and give the student a far better concept of orthopaedic disabilities than do our present more or less haphazard lectures

Under a general title such as "The Locomotor System", the series might include (1) a film on "physical examination", (2) one on "trauma and repair", (3) one on "the aging process", (4) one on "normal and abnormal gaits", and (5) one on "poliomyelitis"

Let us consider how best to teach the essentials of orthopaedic physical diagnosis to a section of second year medical students The subject might be introduced in a ten-minute talk, outlining the ground to be covered The students are then shown a film, which in sound and synchronized, smooth-flowing action demonstrates the principles of inspection, observation of stance, posture, gait, normal ranges of active and passive joint motion, palpation, measurement of leg length, demonstration of atrophy, observation of sensory, reflex, or circulatory change

The film should take not over thirty minutes to show,—and I wish to emphasize that it is not a lecture, but a tool to be used by the lecturer When the lights come on, the instructor distributes the syllabus which covers the film content and includes a check sheet for recording physical findings The instructor then examines a patient in front of the section and the findings are discussed Each student is given the opportunity of taking a history and doing a complete physical examination on the patient He writes up his case, records his findings, his tentative diagnosis, and recommendations This case may be reported as a basis for a grading mark, if the instructor so desires

This, then, is a brief illustrative outline of my concept of the type of film needed A film on "trauma and repair" could introduce the subject of fractures in a vivid way

It is obvious that a number of first-grade teaching films for undergraduate students are needed I would suggest that a committee be assigned to study the problem and to draw up a list of films and their proposed content

Financial sponsorship for production of the films might be solicited from the A O A , from the Academy, from philanthropic foundations, or from anyone who is interested in giving funds to see that medical students are better taught After sufficient funds have been secured, a qualified script writer should be employed and scripts should be prepared for approval Problems of film production and distribution will require careful study

This appears to be a field in which carefully planned, concerted action is necessary I suggest that the time for action has arrived

DISCUSSION

Paul B Magnuson, M D , *Veterans Administration, Washington, D C* (Formerly of Northwestern University, Chicago) There is being planned, by cooperation among a number of government departments, a central pool of teaching films, and we in the Veterans Administration are prepared now to assign funds for the production of teaching films after the necessary scenario has been submitted and approved They can't all be made in one year, that would be impossible However, an extensive program is being planned, and this will include an arrangement whereby those films may be obtained in copy form, either by purchase or loan, by a university or other medical teaching institution

During World War II, I was called upon to do some teaching which consisted of concentrated courses to be given to Army medical officers in periods of six weeks Most of this instruction was necessarily centered on anatomy We did not have an excess of anatomical dissecting material at Northwestern University, so it was necessary to devise ways and means for teaching anatomy so that it would be remembered To that end we undertook the teaching of what we called "constructive anatomy"

In other words, human bones were put together with plasticine and mounted on an old-fashioned retort stand—a scapula, a clavicle, and a humerus, for instance, in slight abduction—and we modeled the whole arm and the whole lower extremity in that way, the students having their anatomical "aphorism" charts and books in front of them and the dissected material at the other end of a long laboratory

The students thought it was very simple at first, until they found that they knew nothing at all about anatomy when they looked at the book They had to walk to the other end of the room to observe the normal anatomical relations, then walk back and reconstruct them, and after about three trips to the other end of the room to see how man was made originally, they began to see the reason for this form of teaching Those men knew more anatomy at the end of six weeks than they ever had known before

The instructor could then ask, "If a bullet strikes a man anteriorly and comes out at the medial edge

of the scapula, about halfway between top and bottom, what structures does it interfere with, and how do you make an examination to find out what structures were injured by the bullet?", and expect to get the correct answer

That method of teaching proves that constructive anatomy impresses the individual with the mechanical aspects of anatomy, but it doesn't correlate with the physiology However, with these visual aids it seems to me that we can make a much greater impression on these young individuals, whether undergraduates or graduates

I found that the graduates probably know less about anatomy, as a rule, than the undergraduates Unless anatomy, physiology, pathology, and embryology are correlated in the minds of these students, they don't remember them very long And when these subjects can be correlated clinically, the students learn something that they remember

DON H O'DONOGHUE, M D, *University of Oklahoma, Oklahoma City* All of us who have been interested in teaching orthopaedic surgery have problems which to us seem very acute I want to speak briefly about one problem which gives us considerable concern

I think we have all been faced with the problem of lecturing to a group of sophomore or junior students, seventy-five or eighty in number, on the subject of fractures or orthopaedic surgery Certainly I feel very much concerned as to whether what I am telling the students is at too low a level for them, so that they go to sleep, or at such a high level that they cannot comprehend it

I think the time has come when these classes should be broken up into smaller groups We are faced with two things One of these is that, in the years before World War II and even antedating that, the number of qualified orthopaedic surgeons was few, so that if the school was fortunate enough to have one good teacher, his teaching capacity was used to the utmost The other is that, during the last War, there was such a scarcity of teaching help in the medical schools that each one who remained at home had to carry his full load and use his time to the best advantage for him and not for the student

In our department, for instance, we have eight or ten qualified orthopaedic surgeons, all of them are certified by the Board, although some have had more experience than others Possibly our students, who get some sixteen hours of didactic instruction in fractures during their junior year, would do better to have one teacher for each eight or ten students, even though he did not happen to be the best teacher on the staff His ability to teach eight or ten men would be better than the ability of the best man of the group to teach eighty students

We all recognize that it is impossible to cover the whole subject of fractures in any such course I think we should teach basic things For instance, if you teach the detail of treatment of fractures about the ankle joint, you have covered in effect the treatment of fractures about any other joint Similarly, the treatment of fractures of the long bones is essentially the same, whether the bone is the femur, the tibia, the humerus, or the radius

W E GALLIE, M D, *University of Toronto, Toronto, Canada* I am glad of this opportunity to take part in this important discussion, because I have had to view the problem from a very different angle from that of the previous speakers Their viewpoint has been that of the orthopaedic surgeon, the Director of the Orthopaedic Department, and the Professor of Orthopaedic Surgery Mine, however, has been not only that of the Professor of Orthopaedic Surgery, but also that of the Professor of Surgery, for I have been head of the Department of Surgery, including all the surgical specialties, for the past twenty years

Most of the speakers have been dissatisfied with the place that orthopaedic surgery occupies in the curriculum and feel that, because of the enormous advance that it has made in the past twenty-five years, it should be given increased time and even complete independence from so-called general surgery

Before coming to any final conclusion in this matter, I think we should pause for a moment and consider just what should be taught to undergraduates Is it possible that the great widening of the field of surgery, with its special branches of urological surgery, neurosurgery, orthopaedic surgery, thoracic surgery, and so on, may have other effects on the teaching of surgery than simply increasing the undergraduate curriculum? The answer, of course, is that it has Within the last ten or fifteen years we have seen the rise of the American College of Surgeons, the Royal College of Surgeons of Canada, the American Boards of Surgery, and of the Surgical Specialties, all of which are committed to the principle that in the future major surgery shall be done only by those who have been properly trained for it This means about five years of postgraduate work

If, then, qualification to practise surgery or one of its specialties is going to require prolonged apprenticeship and postgraduate study, what is the object of expanding the undergraduate curriculum? It seems to me that instead of increasing the amount of time allotted to orthopaedic surgery and all the other surgical specialties, and, indeed, to general surgery itself, we should reduce it If we insist upon more time for the teacl of surgery and its specialties to undergraduates, most of whom are going to be physicians or general titioners, we are simply perpetuating the present unhappy state of affairs, in which much of the s

done by poorly trained men We are placing in their hands the opportunity to do things that we know they should not do

The answer to the question, "What should the department of orthopaedic surgery teach in a medical school?", is threefold

First, it must take part in the teaching of surgery to the undergraduates This teaching should be concentrated on anatomy and physiology as applied to surgery, or general and surgical pathology, with special reference to inflammation, infection, healing of wounds and injuries of all kinds, thrombosis and embolism, gangrene, and so on, and, finally, the taking of histories, the making of a good physical examination, and arriving at a diagnosis You will note that there seems to be no place in this program for teaching orthopaedic surgery All we are supposed to do is to teach the general principles of medicine and surgery by means of the patients who are gathered together on our wards To be a successful teacher of undergraduates, the orthopaedic surgeon must forget his specialty for the moment and go back to the fundamental principles that underlie all specialties

In order that the teaching of surgery may be carried out well, it seems to me that it must be under single direction. To place such a program in the hands of half a dozen separate departments would result in all sorts of confusion and would certainly defeat any plan of teaching general principles The function of the professor of surgery is to plan the course and to see that it is properly carried out

The second great job of the department of orthopaedic surgery is to teach the principles and the practice of orthopaedic surgery to the young men who are being trained in general surgery They will ultimately go out to all parts of the country to take the place of the general practitioners, who at present do most of the surgery It is my thought that a well-trained general surgeon should have at least a six months' assistant residency in orthopaedic surgery and also a period of concentrated experience in fractures It is from these young men, who are passing through the department in their training as general surgeons, that promising candidates can be selected for training as orthopaedic specialists

The third important function of the department is the training of orthopaedic surgeons This, of course, is the most pleasant and interesting of our teaching duties and is the one upon which we must depend for the advancement of our specialty Concerning this I cannot suggest anything that you do not know as well as I do My only comment is that I would not accept a candidate for training as a surgical specialist of any kind who had not had a good basic training in general surgery, and who had not been influenced in his desire for further postgraduate training by his experience in the special department while taking his general surgical training Such a plan makes certain that the candidate understands fully the nature of the specialty he proposes to learn, and it gives the staff an opportunity to form an opinion, before it is too late, as to whether he has the qualities that are necessary for success in that field

J A Freiberg, M D , *University of Cincinnati, Cincinnati, Ohio* This discussion has been very interesting There is one point that seems evident to me in the expanding of the program proposed for the teaching of orthopaedic surgery to undergraduates

Why do we, as orthopaedic surgeons, have to teach anatomy? Obviously, because we think anatomy has not been taught correctly The same reasoning applies to biochemistry and physiology I think our efforts should be directed in the medical schools to see that the various departments of the fundamental sciences plan their particular subjects in the undergraduate program to cover what we believe should be covered I say this because of my close relationship with the Dean in my particular Medical School, knowing that great demands are made on him to increase the teaching time in every department in the Medical School. If we were to grant even one-tenth of the increase in time which is asked for by each department, the school could not function on the basis of four years

We have recently had a professor of anatomy who taught functional anatomy, knowing—and I say this advisedly—as much about joint function as any man in this room We can't all get such professors of anatomy Unfortunately, ours died suddenly a month ago He showed many in our Medical School what can be done, and, therefore, I see no reason why orthopaedic surgeons should have to teach anatomy to freshman medical students Nor do I see why we should enter into the teaching of physiology of bone and joint function, when others of our medical-school faculty should know, and probably do know, more than we do about it, but do not happen to teach physiology the way we feel it should be taught Again, our efforts should be directed toward altering and improving the teaching, rather than doing it ourselves

I do feel that we, as qualified specialists, should give the fundamental training in orthopaedic surgery to the undergraduates The students cannot get this instruction adequately from any other department in our medical schools There are two extremes in instructional programs,—expansion of the time for the specialties and elimination of the teaching of specialties to the undergraduate I recommend a middle road

John W Ghormley, M D , *Albany Medical College, Albany, New York* In the teaching of orthopaedic surgery to students, we have to remind ourselves constantly that we are teaching undergraduates and not postgraduates There is a strong urge to demonstrate unusual cases, especially those which have had excep-

tionally good operative results. There is also a great tendency to discuss new operative procedures, about which the instructor has recently learned and in which he is greatly interested.

Very few students will become orthopaedic specialists. Some will become specialists in other fields, many will go into general practice. We, therefore, give the greatest part of our teaching hours to the demonstration and discussion of cases which can usually be diagnosed by the general practitioner and often treated by him. For example, we would like to have our graduates who are in general practice diagnose osteo-arthritis of a knee by the physical examination and treat the condition by rest, avoidance of extra exertion, especially stairs, reduction of weight, arch supports, possibly a supportive knee bandage, and local heat and massage. We are chagrined when we find that one of our recent graduates is giving these patients vaccines or "shots in the arm", or even twenty minutes of short-wave diathermy.

Our students at present do not spend any time in the operating room, assisting in or observing operations. There are very few didactic lectures. There are assignments in an orthopaedic outline for students, which we have been using for many years, and the students are inspired to study this because they have a weekly written quiz on the assignment. They spend considerable time in the out-patient department and the remainder of their time on the wards. They work up cases which are to come to operation. They may see the operation and they follow the cases postoperatively. They usually present the case to the whole class.

Thus, only a part of the students' time is taken up with a study of hospital diagnostic and operative procedures. Enough time is given to this, however, so that they will know what can be accomplished by such procedures. By this means they will know what cases they can take care of themselves and which ones are better treated by more specialized procedures.

Our theory, then, is that the student should learn general orthopaedic principles so that he can intelligently care for the many orthopaedic problems that he meets in general practice. Let the man who is to become an orthopaedic surgeon get his specialized training in his postgraduate courses.

Arthur Steindler, M.D., *The Children's Hospital, The University of Iowa, Iowa City.* I have heard with the greatest of profit the discussions on the curriculum for orthopaedic training of undergraduates, especially those given by Dr. Green and Dr. Badgley. I am primarily a teacher of graduates; thirty-five years' experience has taught me the errors and the illusions of teaching, when it is not founded upon the very sane and safe principles postulated here.

However, I am discouraged and not satisfied with the situation and the discussion as it has developed so far. It is taken for granted that, if the opportunities are given, that is all that is necessary. The reader must have the introspection, the urge, and the didactic abilities to dispose of a subject in its whole form. I can't conceive of a presentation of a subject that is not in itself a whole; it must refer constantly to the basic foundations and not depend upon basic sciences presented separately.

I believe it is a mistake to think that you can begin where the other departments have left off,—that you need not imbricate and dovetail with the basic sciences. If you hold to strictly specialistic presentation of the subject, where is the assurance that you are not going to separate the student from the common ground of medicine?

The first prerequisite in graduate training seems to me that the student must never be allowed to lose contact with general medicine. I have no trouble making specialists out of my graduates, but I have a hard time making doctors out of specialists.

Paul C. Colonna, M.D., *University of Pennsylvania, Philadelphia.* From the many ideas brought forth in the discussion, it is clear that the teachers in the various medical schools throughout the country are aware of the need for improvement in the teaching of orthopaedic surgery during the formative years of the medical student. Incidentally, I am glad to note that we are getting away from the term orthopaedics and designating our specialty as orthopaedic surgery.

Our instruction in the past has largely been devoted to the graduate and postgraduate student, but if we wish to raise the quality of young men going into this specialty we should begin by interesting the medical student in this subject.

Many excellent suggestions have been made this afternoon and I have been particularly impressed with three approaches to this problem: first, to have a few orientation lectures during the first two years and didactic and bedside teaching in the third and fourth years; second, the symposium method of teaching, in which the different departments of the preclinical and clinical divisions of the medical school can take part, so that the student obtains a broad view of the particular problem discussed and understands the usefulness of careful history-taking, examination, and differential diagnosis; third, the almost untapped field of utilizing audio-visual aids in teaching.

It is, of course, recognized that the most important factor in this or any other subject is a stimulating teacher, who has the ability to arouse scientific curiosity in the group to which he is speaking, whether it be with small groups in bedside teaching or with larger groups.

PROFESSOR GEORGE PERKINS, *St Thomas Hospital, London, England* Orthopaedic surgery can be considered either as a specialized branch of surgery or as a small section of medicine that typifies the whole of medicine If orthopaedic surgery is to be considered as a specialized branch of surgery, we must consider how many hours the average student should devote to that specialty

The crucial fact that most students are eventually to become general practitioners is often overlooked In this age of specialization, we are inclined to forget that the prime aim of a medical school is to produce what laymen call doctors We have first of all to make this student a doctor

Medical knowledge is like our national debt It is always on the increase Year by year, the mass of knowledge accumulates and specialists become more numerous Every specialist demands that the students should spend an undue proportion of their time in his own specialty It always amuses me to ask a specialist how many lectures he thinks should be given in his subject The anaesthetist wants twelve, the endocrinologist wants twelve, the gynecologist wants twelve, and the psychologist may want twenty-four If all these men were given what they demand, the student would be attending lectures all day long, and he would have no time for examining a patient or, which is more important, for talking to a patient, let alone time in which to sit and think

It seems reasonable that the amount of time devoted to any subject should be related to its frequency in the ordinary general rounds of a practitioner Based on this premise, orthopaedic surgery is one of the major specialties, because patients with complaints like flat feet, lumbago, and the like, form a large proportion of a general practitioner's practice However, the claimants on a student's time are so numerous that the orthopaedic surgeon must moderate his demands In my school the authorities allot six lectures a year to orthopaedic surgery It will always be impossible to cover the whole of orthopaedic surgery in six lectures

What then ought the lecturer to deal with,—subjects of interest to himself, such as bone tumors and arthroplasty of the hip, or subjects which are going to be of use to the general practitioner afterward, such as metatarsalgia? As the general practitioner may see a hundred cases of metatarsalgia to one bone tumor, obviously metatarsalgia should have the preference I think the orthopaedic surgeon has to reconcile himself to giving only a very few lectures and those on dull subjects, if orthopaedic surgery is to be considered as a special department of surgery

In my Hospital, what we call the apprentice system prevails The student spends six months as an in patient surgical dresser, during which he spends most of the day in the wards, where he learns surgery from one so-called general surgeon He spends another six months in medical wards, learning medicine from one general physician For the rest of his tutelage he is free to go on ward rounds, attend out-patient clinics, or visit special departments During that period he is not attached to any particular man The result is that the student gets to know intimately only the physician or surgeon to whom he is apprenticed, and he gets the impression that the medicine and surgery which are practised in special departments are of no moment

Let us consider the other method of looking at orthopaedic surgery,—namely, as a small section of medicine that illustrates and typifies the whole of medicine This, I think, should be its role in an undergraduate medical school

The orthopaedic surgeon can, by reference to his own specialty, teach almost all the principles of medicine He can show examples of inflammation, degeneration, disordered growth, new growth, repair, disordered nervous activity, endocrine disturbance, and faulty nutrition These are examples which are visible, the pathological processes can be seen and felt In fact, only the dermatologist has a better opportunity for teaching the principles of medicine Moreover, when the orthopaedic surgeon operates upon a patient, he is able to judge the results of his treatment It does no good for him to try to gloss over his failures because his patient will not let him As a consequence, the orthopaedic surgeon is much more inclined to hesitate and to ask himself "If I do this to my patient, shall I benefit him or shall I do him harm?"

How much time should be allotted to orthopaedic surgery? This depends not only upon the intrinsic importance of the specialty, but upon the teaching ability of the surgeon in charge I can conceive of an orthopaedic department having at its head an extraordinarily fine technician who is a poor teacher If I were the dean in that school, I would allow the students to pay only a cursory visit to the orthopaedic department On the other hand, I can conceive of the orthopaedic surgeon, besides being a brilliant technician, being an inspired teacher I can conceive of that much more easily because I had the good fortune to be brought up and taught by a very famous teacher, the late Mr Rowley Bristow If I were dean, I would send students as often as possible to the orthopaedic department which had a man like Mr Bristow at its head The difficulty is that the dean cannot be constantly changing the student's curriculum

When the student goes into the wards for his in-patient dressing, I would not allow him to spend the whole of that time with one man, but make him rotate so that he would see half a dozen different types of surgeons Sitting in succession at the feet of different surgeons would disabuse his mind of the idea that surgery can be learned only from the general surgeon With this system the student would learn his surgery and develop his surgical mind from the man who taught best, whether that surgeon be an abdominal surgeon, a plastic surgeon, an orthopaedic surgeon, or any other kind of surgeon

I believe the orthopaedic surgeon should teach general principles of medicine For example, he might take three such conditions as hyperthyroidism, peptic ulcer, and perhaps synovitis of the knee as constituting s

imilar problem of what to do if an organ of the body secretes more than is needed, because the principle of treatment is the same You either diminish the amount of secretion or neutralize it, or you take away part of the organ that is secreting it

Finally, concerning how the surgeon should teach, I believe the more dogmatic the teacher is, the better is the teaching However, the teacher should mitigate the effects of his dogmatism by instilling skepticism into the minds of the students

F H ARESTAD, M D , *Council on Medical Education and Hospitals, American Medical Association, Chicago, Illinois* First, let me express to this Committee the appreciation of the Council in having an opportunity to participate in this meeting

The Council, as you know, is primarily concerned with medical education, both at the undergraduate and the graduate levels Of course, we are deeply interested in the opinions and the experiences of this group, and the planning of effective teaching in the field of orthopaedic surgery This is a particularly opportune moment for a meeting of this type in relation to the work of the Council, because we will begin very shortly to conduct another major survey of medical education in the United States, similar to the program that was carried out in 1934 to 1935 by Dr Weiskotten, who at the present time is Chairman of the Council From this discussion and the presentation of papers this afternoon, I assume that the major objective is to develop a model plan that can be used as a guide to orthopaedic departments in the various schools throughout the country

I think we should keep in mind that while a guide is useful, it should not be developed as a fully standardized plan, because you can never really standardize teaching itself It can be useful, I am sure, in developing some suggested methods, particularly an earlier introduction of students to an understanding of orthopaedic surgery as a whole, so that they may be able to comprehend more readily what is involved when, in their third and fourth years, they come into actual contact with orthopaedic problems I was particularly impressed with one of the objectives that was stated by one of the discussors, who said that the plan of teaching should also serve to stimulate the student This inspirational teaching comes from the men who, by special qualities, interest, and enthusiasm, are able to stimulate their students

I believe the meeting has also shown the need for further conferences of this type, as many different views have been expressed that will need further consideration in times to come

I should like to read a statement which I brought with me that may express in some measure the views of our office, you will sense, as I read this, that we are thinking primarily in terms of practical education, less in terms of didactic instruction

"Medical directors and medical educators as a group believe that in the teaching of the surgical specialties, stress should be placed primarily on the basic principles of pathology, physiology, diagnosis, and therapy rather than on techniques and details As much as possible, instruction should be correlated with instruction in general medicine and surgery and with the preclinical sciences

"It is generally recognized that there is not time in the undergraduate course to train students in the techniques of the various surgical specialties Adequate training in surgical technique can be acquired only during the internship and residency years Therefore, it is recommended that in the undergraduate teaching of the surgical specialties, expositions and discussions of technical procedures be reduced to the minimum that is necessary for an understanding of the principles of therapy With the elimination of detailed instruction in surgical techniques, there has been in the past twenty years a general reduction in the number of hours assigned to the various surgical specialties in the undergraduate curriculum

"In the surgical specialties, as in all other clinical subjects, the course of instruction should be built primarily around work with patients with a minimum of straight didactic instruction Whenever possible, the student should be given the opportunity to work individually under supervision in the out-patient department or on the hospital wards"

There is one other point that I should like to raise as a question of approach It was mentioned today, I believe by Dr Green, that orthopaedics ought to have 20 to 25 per cent of the time devoted to surgery I am just wondering if that is the right approach to the problem, although it is a good statement to be brought before a conference of this type because all of you have an opportunity to carry these thoughts and discussions back to your schools

The reason I'm questioning the approach is that it implies you are going to take something away from surgery or from some other specialty Actually, surgery will need whatever time is required to do its work, so will all the other specialties in medicine The time element should be considered from the standpoint of the entire curriculum, as any additional time that is needed might come from obstetrics, from internal medicine, from psychiatry, from surgery, or from some other field, but would not necessarily be a reduction of general surgical training in order to give orthopaedic surgery an additional amount

I believe also that Dr Green brought out an important point, mentioning that time itself is not always the most important factor Rather it is the effective utilization of time, and therein lies that quality of teaching which enables instructors to present a subject with interest and with the greatest value to students

SUMMARY

By A Bruce Gill, M D

At first glance it might appear that the opinions expressed by the speakers who have participated in this symposium are very diverse and even, at times, irreconcilable, but a careful study of them reveals that there are fundamental points on which many of the speakers agree

1 The majority of medical students will become general practitioners The student's undergraduate training and his subsequent experience as an intern in a hospital must fit him to enter upon his practice If he has not had good basic training in the medical school, he will be greatly handicapped during his internship When he has completed his internship, he has not been trained as a specialist The general practitioner will be called upon to examine and to treat all sorts of diseases and injuries, and at times to refer a patient to the proper specialist, if one is available Undergraduate teaching must, therefore, include the basic principles of the specialties, but should be limited to the fundamental things which every "doctor" should know

It might be mentioned that the teaching of the basic sciences should be subject to the same limitation The medical school should not graduate specialists in anatomy, physiology, pathology, biochemistry, or bacteriology The question may well be asked whether in medical schools too much time and too much emphasis is given to one or more of these basic sciences Should it be essentially a school for pure science or a school of applied science? If the latter, then the application of the pure sciences to the practice of medicine should go hand in hand with the teaching of the basic sciences For example, descriptive anatomy and functional anatomy should be taught together If an orthopaedic surgeon should be called upon to assist in the anatomical department in teaching body mechanics and its application in surgery, no more time would be required than is at present allotted in the curriculum In fact, time could be saved and the students would receive more interesting and profitable teaching

2 Orthopaedic surgery is a large and important branch of surgery as a whole The teaching of the basic facts and principles of the surgery of the musculoskeletal system can be done better by an orthopaedic surgeon than by a visceral surgeon Inasmuch as the fundamental principles of surgery are applicable to all parts of the body, the orthopaedic surgeon is participating in the teaching of surgery as a whole and is demonstrating the application of the basic sciences and of medical and surgical principles in his own particular field of surgery Furthermore, the opportunity of teaching methods of complete and accurate examination are unexcelled in any other branch of surgery As emphasized by many of the speakers, the orthopaedic surgeon should not be teaching his students to become specialists, but he should be given the opportunity in the curriculum to do the things which have been mentioned and which he is pre-eminently fitted to do This means that the ability and the service of the orthopaedic surgeon should be utilized much more commonly than they are at present in many of our medical schools

3 An intimate and unselfish cooperation of all departments of surgery is essential to the best teaching If one administrative officer should head the entire department of surgery, he should be as broadminded and have as wide a vision as Dr Gallie The chiefs of all departments of surgery should meet in conference, whether or not there is one administrative head, to determine what and how and by whom surgery should be presented to the students

My own observation over a period of many years has been that too often in our medical schools the various departments of teaching have, from the very circumstances of their inception and development, pursued each its own independent way, with lack of cooperation and even with jealousy and conflict among themselves

There should be a unity in the teaching of medicine, each part contributing its quota to the unified whole What that whole should be cannot be determined by any one man or by a small dictatorial group of men It must be attained by free and rational discussions by the heads of all the various departments of teaching

4 There is no difference in opinion as to the value of the use of audio-visual methods in teaching The remarks of Dr Chandler and Dr Barr deserve full consideration Means should be taken whereby audio-visual aids may be available in all of our schools of medicine

Note The Committee regret that, because of restrictions of space, it has been necessary to omit the discussions prepared by the following men Lenox D Baker, M D, Durham, North Carolina, Philip Lewin, M D, Chicago, Illinois, Paul B Steele, M D, Pittsburgh, Pennsylvania, and Peter B Wright, M D, Atlanta, Georgia

News Notes

THE AMERICAN ACADEMY OF ORTHOPAEDIC SURGEONS

The Sixteenth Annual Meeting of The American Academy of Orthopaedic Surgeons will be held at the Palmer House, Chicago, January 22 to 27, 1949, under the presidency of Dr Myron O Henry

Registration will begin at nine o'clock Saturday morning, January 22 Scientific and technical exhibits will be ready for inspection at that time During the afternoon, the Audio-Visual Program will be presented under the chairmanship of Dr Charles N Pease, this program will be continued on Sunday morning from nine to twelve o'clock

The Instructional Courses will begin at two o'clock Sunday afternoon and continue until noon on Monday A good variety of courses will be offered by a distinguished faculty

On Monday evening, the Instructional Course dinner will be given, followed by an "Information Please" program similar to the one presented last year, at that time interesting cases will be presented to "stump the experts"

On Monday afternoon, the first session of the Academy will be held, and the new members will be presented with their certificates Dr Henry will give his Presidential Address, which will be followed by the first Executive Session

Tuesday morning and afternoon, Wednesday morning and afternoon, and Thursday until noon will be occupied by an excellent Scientific Program, which has been arranged by the Program Committee under the chairmanship of Dr Lenox D Baker The second Executive Session will be held at noon on Thursday

The annual banquet of the Academy will be held on Wednesday evening Alumni dinners and other special groups will meet this year on Tuesday night, rather than on Monday night as in the past

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THE AMERICAN SOCIETY FOR SURGERY OF THE HAND

The American Society for Surgery of the Hand will hold its Fourth Annual Meeting in Chicago on January 21 and 22, 1949 The clinical program follows

FRIDAY, JANUARY 21

9 30 A M

Primary Nerve and Tendon Repair By Joseph L Posch, M D , Detroit, Michigan (by invitation)

Primary Tenorrhaphy By Vinton E Siler, M D , Cincinnati, Ohio

Treatment of Severed Flexor Tendons in the Flexor Sheaths of the Fingers By R Sterling Mueller, M D , New York, N Y

Acute Suppurative Tenosynovitis of the Hand By J Edward Flynn, M D , Boston, Massachusetts

Median-Nerve Neuritis By George S Phalen, M D , Cleveland, Ohio

2 00 P M

Plastic Repair of the Cleft between the Thumb and Index Finger By Gilbert L Hyroop, Lieutenant Colonel, M C , Valley Forge General Hospital

Thumb Web Contracture By L D Howard, Jr , M D , San Francisco, California

Adduction Contracture of the Thumb By William Littler, M D , New York, N Y

Arthroplasty for Ankylosis of the Metacarpophalangeal Joint By F L Liebolt, M D , New York, N Y (by invitation)

Dupuytren's Contracture By J M Bruner, M D , Des Moines, Iowa

SATURDAY, JANUARY 22

9 30 A M

Skeletal Reconstruction in the Hand By William Metcalf, M D , Hines, Illinois

Relationship of Superficial and Deep Reconstructive Surgery of the Hand By W Brandon Macomber, M D , Albany, New York

Xanthoma of the Hand By Thomas W Stevenson, M D , New York, N Y

Presentation of Cases By Sumner L Koch, M D , Michael L Mason, M D , and Harvey S Allen, M D , Chicago, Illinois

The clinical meetings will be held at Thorne Hall, Northwestern University, 940 Lake Shore Drive

On Friday evening at six-thirty, there will be a dinner for members at the University Club, 76 East Monroe Street A business meeting will follow the dinner

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The Western Orthopaedic Association, under the presidency of Harold E Crowe, M D , will hold its next Annual Meeting on October 19, 20, and 21, at the Biltmore Hotel, Santa Barbara, California

Hemostatic Agents With Particular Reference to Thrombin, Fibrinogen and Absorbable Cellulose Walter H Seegers, M S, Ph D, and Edward A Sharp, M D, Sc D Springfield, Illinois, Charles C Thomas, 1948 $4 75

The authors have condensed into ninety-six small pages the recent work on their subject, salient points in the 370 references they cite have been summarized into two hours of easy reading The outstanding contributions of the writers in the purification of bovine thrombin, and their demonstration of its clinical utility and safety, as well as the major role of the second author in the studies on absorbable or oxidized cellulose have given them a first-hand knowledge of their field However, they have not attempted to make us experts by this volume, but have confined their remarks chiefly to those phases of the subject of use to surgeons

Their first chapter on the current concepts of clotting mechanisms is a model of lucid presentation of a complex subject Although they do not themselves point out the clinical applications of some of the data they give, one notes that "the higher the temperature below 50° C, the more rapidly a fibrin clot forms" and that "heat inactivation of thrombin begins at about 40° C" From these two facts one is reminded that the use of heat a little above 40 degrees centigrade is still a worthwhile adjuvant to the placement of gelatin sponge or oxidized cellulose soaked in thrombin for hemostasis Again they point out that plasma contains so much antithrombin that a given amount of plasma, when standing mixed with an excess of thrombin, will destroy ten times as much as the total potential thrombin yield from the same amount of plasma Hence at operation, one should not contaminate the stock supply of thrombin by returning blood-soaked pieces of sponge or cellulose to it

Of special interest to orthopaedic surgeons are these facts (1) Thrombin as the dry powder may be rubbed into bleeding bone surfaces with prompt arrest of hemorrhage (2) Oxidized cellulose slows the reparative processes in bone fractures, and hence should not be used where rapid formation of callus is desired. This property may, however, be utilized in cases in which delay of ossification is desirable, as, for example, in the reconstruction of ankylosed joints (3) Oxidized cellulose will not disintegrate and be absorbed in a closed area harboring infection Only when the hemostatic effect of the cellulose offsets the disadvantage of post-operative drainage of the infection should it be used under such circumstances

Clinical applications for purposes other than hemostasis are mentioned The most important of these to the orthopaedic surgeon is the account of nerve suture by fibrin fixation Whether this represents a significant improvement in technique will be determined only when the end results of the nerve sutures done by this method in World War II are compared with those of other methods No figures of this type are available as yet

The authors are to be congratulated for assembling so helpful a volume in such a succinct form

Take Up Thy Bed and Walk David Hinshaw New York, G P Putnam's Sons, 1948 $2 75

Mr Hinshaw discusses the problem of rehabilitation of the physically handicapped individual, but his story concerns essentially the progress of this work at the Institute for the Crippled and Disabled in New York City The Institute did pioneer work in this field as far back as 1917, and in World War II provided training courses in rehabilitation procedures and techniques for members of the Armed Services Courses for the handicapped are provided at the Institute in such skills as mechanical drawing, welding, jewelry making, watch repairing, sewing, and the like As stated "Vocational rehabilitation is the process of developing and restoring the handicapped individual, in terms of his total situation, to the fullest physical, mental, social, vocational and economic usefulness of which he is capable"

The importance is stressed of treating the patient as a whole, and not merely his disease Special emphasis is laid upon orthopaedic conditions The scope of physical medicine is discussed, and mention is made of the rehabilitation program sponsored by the Veterans Administration The underlying theme of the book, however, is a plea for sympathetic understanding and help for the physically handicapped

Guide for an Advanced Clinical Course in Orthopedic Nursing New York, National League of Nursing Education, 1948 $0 60

This pamphlet, prepared by the Subcommittee on Orthopaedic Nursing of the Committee on Postgraduate Clinical Nursing Courses, is No 6 in a series dealing with the various branches of nursing which the qualified graduate nurse may enter The objectives of a clinical course in orthopaedic nursing—namely the "ability to utilize orthopedic principles in all nursing situations and to plan and carry out expert nursing for patients with orthopedic conditions"—are mentioned, and a teaching guide for such a course is set forth

Wanted

The Editorial Office of *The Journal* is constantly having calls for back issues of *The Journal* and desires to know where copies of the following issues may be obtained when needed

The American Journal of Orthopedic Surgery

1903–1904 Vol I, Nos 1, 2, 3, and 4 August, November 1903, February, May 1904
1904–1905 Vol II, Nos 1, 2, 3, and 4, August, October 1904, January, April 1905
1905–1906 Vol III, Nos 1, 3, and 4, July 1905, January, April 1906
1906–1907 Vol IV, Nos 1, 2, 3, and 4, July, October 1906, January, April 1907
1907–1908 Vol V, Nos 1, 2, 3, and 4, July, October 1907, January, April 1908
1908–1909 Vol VI, Nos 1, 2 3, and 4, August, November 1908, February, May 1909
1909–1910 Vol VII, Nos 1, 2, 3, and 4 August, November 1909 February, May 1910
1910–1911 Vol VIII, Nos 1, 2, 3, and 4 August, November 1910, February, May 1911
1911–1912 Vol IX, Nos 1, 2, 3, and 4, August, November 1911, February, May 1912
1912–1913 Vol X, Nos 1, 2, 3, and 4 August, November 1912, February, May 1913
1913–1914 Vol XI, Nos 1, 2, 3, and 4 July, October 1913, January, April 1914
1914–1915 Vol XII, Nos 1, 2, 3, and 4 July, October 1914, January, April 1915
1915 Vol XIII, Nos 1 and 2, July, October
1916 Vol XIV, All twelve issues
1917 Vol XV, Nos 1, 2, 3 4, 5, 6, 7, 8, 9, and 10, January, February, March, April, May, June, July, August, September, and October
1918 Vol XVI, Nos 1, 2, 3, 4, 9, and 12 January, February, March, April, September, and December

The Journal of Orthopaedic Surgery

1919 Vol I (Old Series Vol XVII), Nos 1, 2, 3, 4, 7, 9, 10, 11, and 12, January, February, March, April, July, September, October, November, and December
1920 Vol II (Old Series Vol XVIII), Nos 2, 3, 4, 7, 8, 9, 10, and 12, February, March, April, July, August, September, October, and December
1921 Vol III (Old Series Vol XIX), Nos 1, 2, 3, 4, 6, 9, 10, 11, and 12, January, February, March, April, June, September, October, November, and December

The Journal of Bone and Joint Surgery

1922 Vol IV (Old Series Vol XX), Nos 1 and 2, January and April
1923 Vol V (Old Series Vol XXI), Nos 1, 2, 3, and 4, January, April, July, and October
1924 Vol VI (Old Series Vol XXII), Nos 1, 2, and 4 January, April, and October
1925 Vol VII (Old Series Vol XXIII), No 1, January
1926 Vol VIII (Old Series Vol XXIV), Nos 2 and 3, April and July
1927 Vol IX (Old Series Vol XXV), Nos 1, 2, and 4, January, April, and October
1928 Vol X (Old Series Vol XXVI), Nos 1, 2, and 3, January, April, and July
1929 Vol XI (Old Series Vol XXVII), Nos 1 and 2, January and April
1930 Vol XII (Old Series Vol XXVIII), No 1, January
1931 Vol XIII (Old Series Vol XXIX) No 1, January
1934 Vol XVI (Old Series Vol XXXII), Nos 1 and 4 January and October
1937 Vol XIX (Old Series Vol XXXV), Nos 1, 3, and 4, January, July, and October
1938 Vol XX (Old Series Vol XXXVI), Nos 2, 3, and 4, April, July, and October
1939 Vol XXI (Old Series Vol XXXVII), Nos 1, 2, 3, and 4, January, April, July, and October
1940 Vol XXII (Old Series Vol XXXVIII), No 1, January
1944 Vol XXVI (Old Series Vol XLII), Nos 2 and 4, April and October
1947 Vol 29 (Old Series Vol 45), Nos 2 and 3, April and July

Any reader having copies of the above, which he is willing to dispose of, is requested to correspond with the Editor

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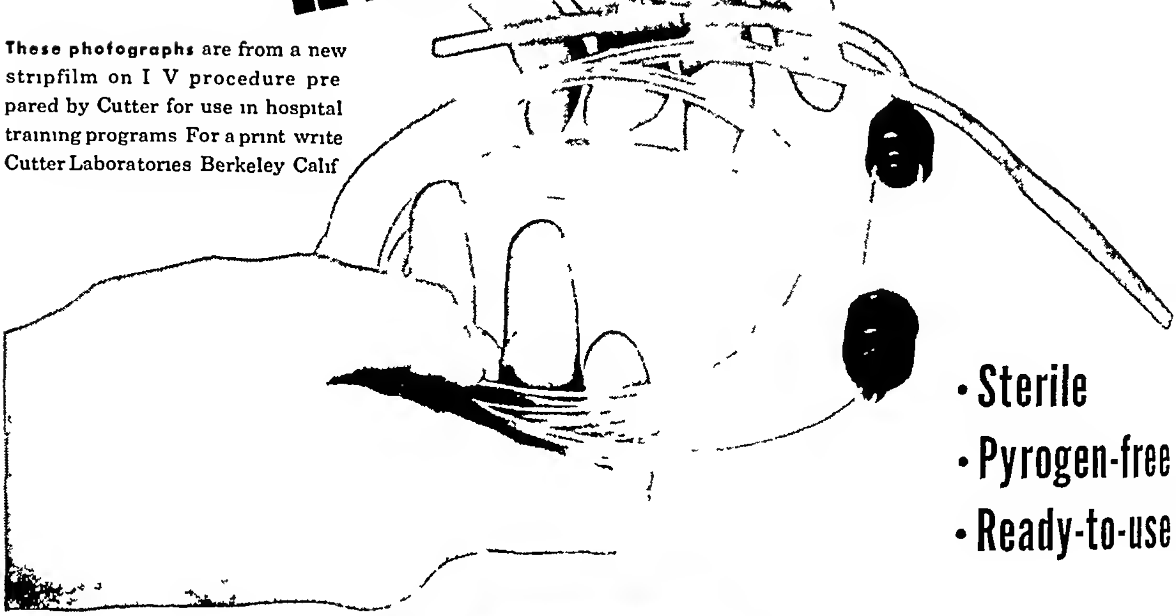

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The Journal of Bone and Joint Surgery*

American Volume

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The Journal of Bone and Joint Surgery (American Volume) is issued quarterly—in January April July and October The 1949 subscription price payable in advance is $10 00 Single copies $2 50

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Suggestions for Contributors

While *The Journal of Bone and Joint Surgery* is published by The American Orthopaedic Association and The British Orthopaedic Association, contributions of interest to orthopaedic surgeons are welcome from all countries of the world

Manuscripts offered for publication in the American Volume should be sent to the Editor, *The Journal of Bone and Joint Surgery,* 8 The Fenway, Boston 15, Massachusetts

Manuscripts submitted for publication in the British Volume should be sent to the Editor, *The Journal of Bone and Joint Surgery,* 45 Lincoln's Inn Fields, London, W C 2, England

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All articles are acknowledged as soon as received, and a reply is sent as to their disposition as soon as possible after that date Since the manuscripts are read by members of the Board of Associate Editors and often are discussed at the meetings of the Board, there may be unavoidable delay

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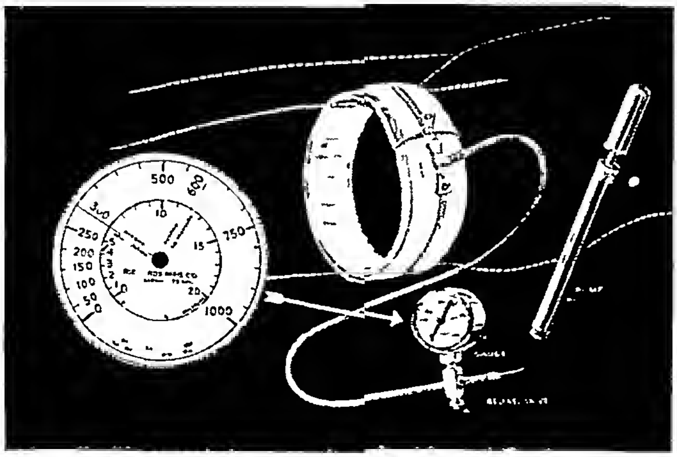

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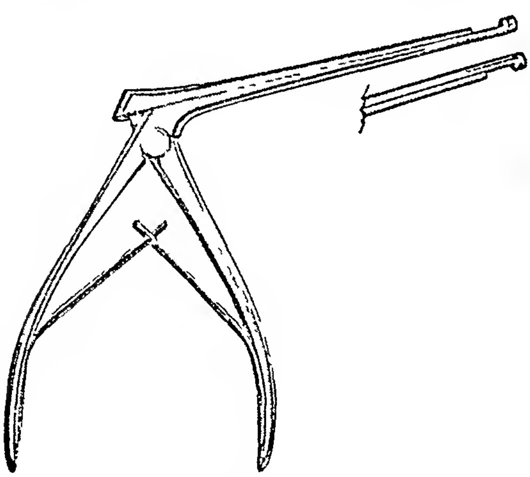

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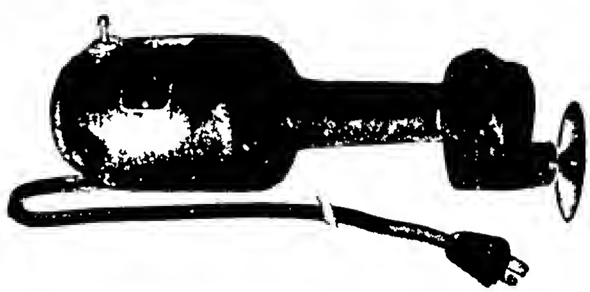

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TENDON TRANSFERS AND ARTHRODESES IN COMBINED MEDIAN AND ULNAR NERVE PARALYSIS*

BY J. WILLIAM LITTLER, M.D., NEW YORK, N. Y.

The importance of the intrinsic muscles in relation to hand function becomes apparent following a lesion of both the median and ulnar nerves. A common injury may involve these two nerves in the brachium or at the wrist, where they are closely related. The functional loss is great and compensation is difficult. Excellent extrinsic-muscle function and good sensation may return after nerve suture, but the hand frequently is clawed and rendered almost useless through the loss of thumb opposition and finger extension (Figs. 1-A and 1-B). The pulp atrophy which often accompanies nerve injury is a severe disability and makes the already impaired pinch mechanism ineffectual.

This deformity can be overcome partially by appropriate tendon transfers and arthrodeses, designed to restore muscle balance and to bring the thumb and fingers into a functional position. An effort has been made to simplify the transfer of the tendons, as it is impossible to compensate for all the complex intrinsic-muscle functions. Frequently there is a dearth of transferable tendons, so that only the most important intrinsic functions can be considered. Successful transfers depend upon adequate strength and amplitude in the tendons, proper mechanics, good joint mobility, and freedom of the tissues from cicatrix.

The maintenance of a mobile hand, free from contracture, demands persistent effort during the period of nerve regeneration and prior to transfer of the tendons. Frequently the blood supply to the hand has been impaired, resulting in pain and stiffness. If a sympathetic-nerve block improves the circulation, a dorsal sympathetic neurectomy may be indicated. Repeated joint exercises through the complete normal range, coupled with dynamic splinting to maintain the hand in a good position, will greatly enhance the final functional result. Special effort must be made to prevent an adduction contracture of the thumb, a fixed hyperextension deformity of the metacarpophalangeal joints secondary to contracted collateral ligaments, and flexion deformities of the interphalangeal joints (Figs. 2-A, 2-B, and 2-C). Excision of the collateral ligaments in an effort to gain metacarpophalangeal flexion when interosseous-muscle paralysis is present may further cripple the hand by provoking the development of a marked ulnar deviation of the fingers. By leaving intact the collateral ligament on the radial side of the joint, enough relaxation can often be obtained to permit flexion without undue loss of stability. If the procedure is adopted, great care must be exercised to prevent damage to the extensor hood, which serves primarily to hold the extensor tendon in place over the apex of the metacarpophalangeal joint.

Opposition can be restored to a mobile thumb by prolongation of any active wrist flexor or extensor tendon with a free graft, or by the use of a finger flexor of sufficient length so that it pulls from an insertion on the medial aspect of the proximal phalanx of the thumb, over the lateral aspect of the metacarpophalangeal joint toward the pisiform, superficial to the palmar fascia (Fig. 3). The Bunnell silk technique is used between

* Read before the American Society for Surgery of the Hand, Chicago, Illinois, January 23, 1948.

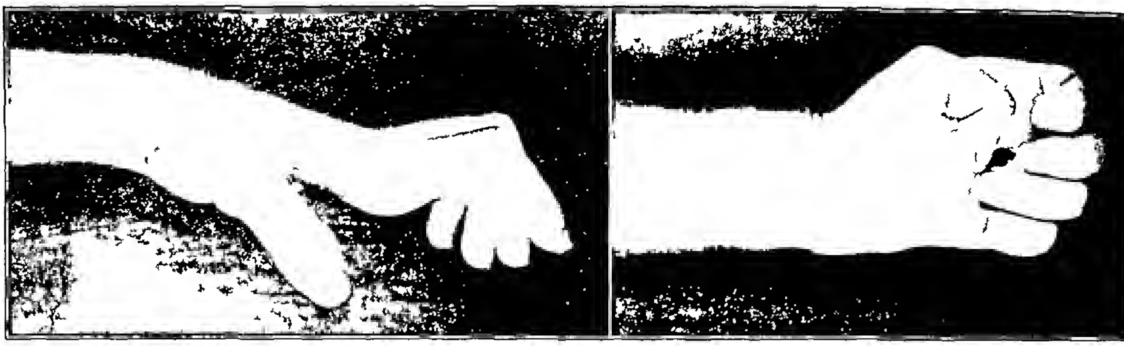

FIG 1-A FIG 1-B

Complete paralysis of intrinsic muscles, showing typical deformity The atrophy, muscle imbalance, and loss of thumb opposition are clearly demonstrated by the flattening of the palm, external rotation of the thumb, and hyperextension of the metacarpophalangeal joints of the fingers Here the action of the long extensors and flexors is unopposed, and tendon transfers are necessary to restore balance and opposition Good sensation and extrinsic-muscle function were gained through nerve suture in the brachium

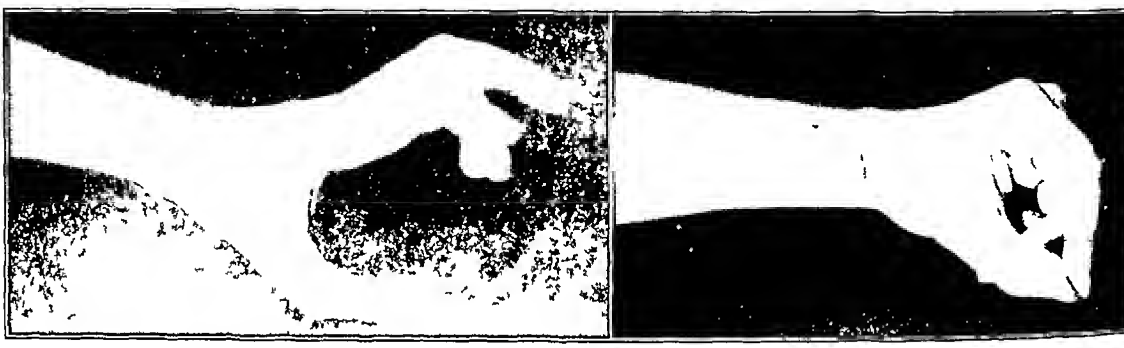

FIG 1-C FIG 1-D

A useful hand resulted through the restoration of thumb opposition and stabilization of the meta carpophalangeal joints

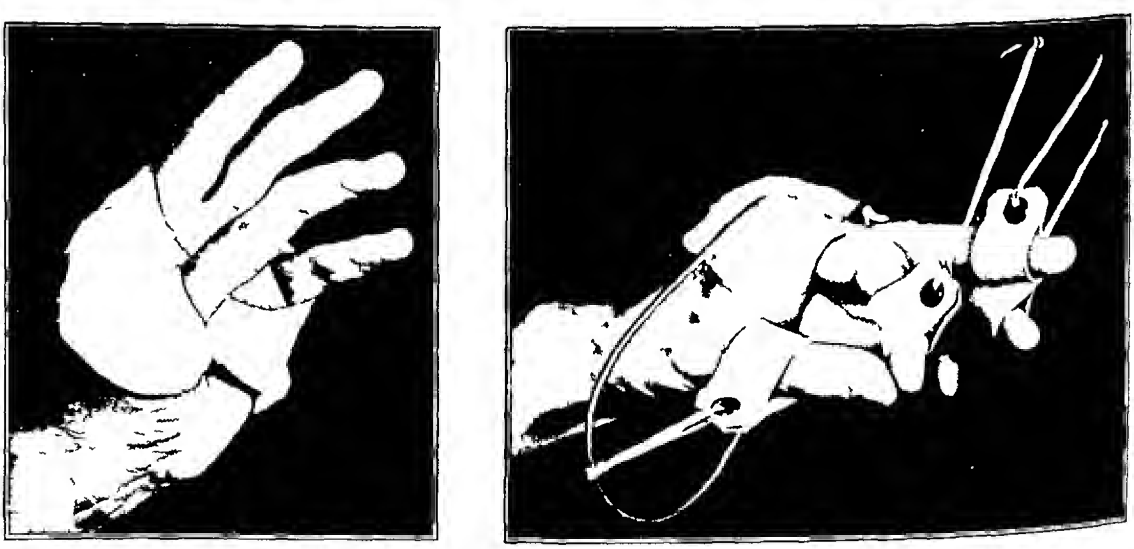

FIG 2-A FIG 2-B

Fig 2-A Basic splint designed to maintain the functional position of the hand and to prevent deformity in paralysis of the intrinsic muscles The metacarpal arch is well developed, the metacarpophalangeal joints are prevented from hyperextending, and the thumb is held abducted at a right angle to the palm in the functional position With hyperextension checked, the intact long extensors can act to extend the middle and distal phalanges

Fig 2-B Basic splint with traction apparatus for correcting the adducted thumb and flexion contractures of the interphalangeal joints

the graft and the transferred tendon, and his removable steel-wire technique is used at the insertion If an extensor tendon is used, the free graft is passed subcutaneously around

the ulnar aspect of the hand. When the flexor carpi ulnaris is used, it is prolonged to the thumb with a free graft through a loose pulley at the pisiform. A finger flexor, if available, is excellent for motor power, and, when opposition has been lost through a local or low median-nerve injury, the procedure of choice is a transfer to the thumb of the normally functioning sublimis tendon of the ring finger, the flexor carpi ulnaris tendon being utilized as a pulley.

The abductor pollicis brevis alone is able to produce excellent opposition of the thumb, and it is the most important muscle of the thenar group[3,6]. By virtue of its insertion into the base of the proximal phalanx and into the long extensor, this muscle can stabilize the metacarpophalangeal joint in abduction, flexion, and pronation, and can assist extension of the terminal phalanx,—the essential functional components of opposition. Good results have been obtained by suturing the transferred tendon to the tendinous insertion of the paralyzed abductor pollicis brevis. The transfer is simplified and the correct insertion is assured.

If a wrist fusion is a desirable part of the reconstructive program, the opponens transfer should precede it, so that relaxation of the transferred tendon by wrist flexion can be obtained. When splinting has failed to correct an adduction contracture of the thumb and opposition is to be restored, the first metacarpal can be mobilized by excision of the contracted first dorsal interosseus, the flexor pollicis brevis, the adductor pollicis muscles, and the fascia. However, if this is done, a fusion of the metacarpophalangeal joint at 20 degrees of flexion or an adductor-tendon transfer may be necessary for stabilization.

The extensor pollicis longus is a direct antagonist to opposition, and in many cases the tendon is adherent

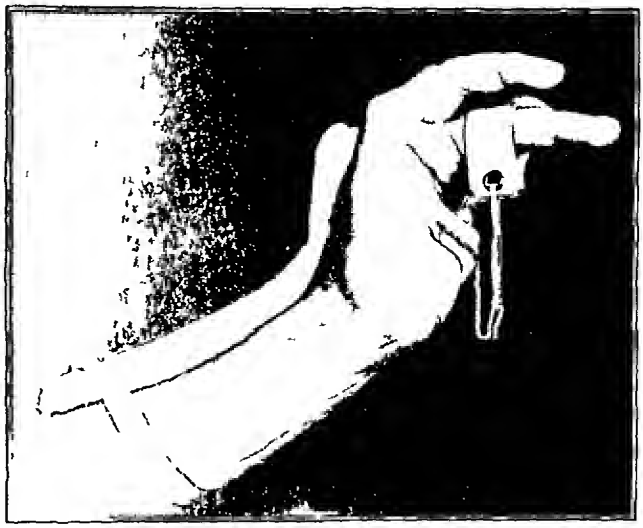

Fig 2-C

Correction of fixed hyperextension deformity of metacarpophalangeal joints by elastic traction. The pull is maintained at right angles to the proximal phalanges from a point overlying the proximal interphalangeal joints. Wrist extension prevents forward slipping of splint and interference of palmar bar with flexion of metacarpophalangeal joint. Thumb traction is not shown. The pull is directed toward the tubercle of the navicular.

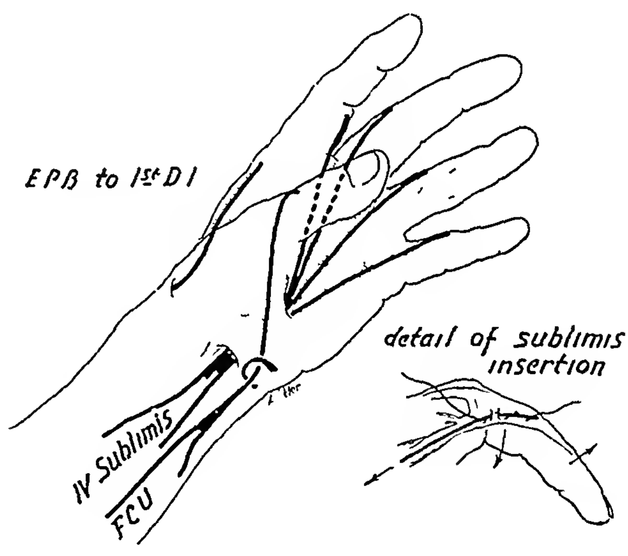

Fig 3

Essential tendon transfers to restore opposition and the balance between the finger extensors and the intrinsic muscles in median and ulnar nerve paralysis. Shaded areas represent intrinsic muscles, compensated for by transfers. In some cases it is necessary to stabilize in flexion for a hyperextension deformity of the thumb metacarpophalangeal joint. A sublimis tendon is severed at the proximal interphalangeal joint, withdrawn at the wrist, and split into four divisions. Through a dorsolateral finger incision, the dorsal aponeurosis and lateral band are exposed, and a probe is passed along the lumbrical canal and tendon sheath to the wrist, where the sublimis divisions are caught, withdrawn, and sutured. Various muscles are used for power, but the principles of the transfers are unaltered.

E P B to 1st D I = extensor pollicis brevis to first dorsal interosseus

IV Sublimis = extensor digitorum sublimis to fourth digit

F C U = flexor carpi ulnaris

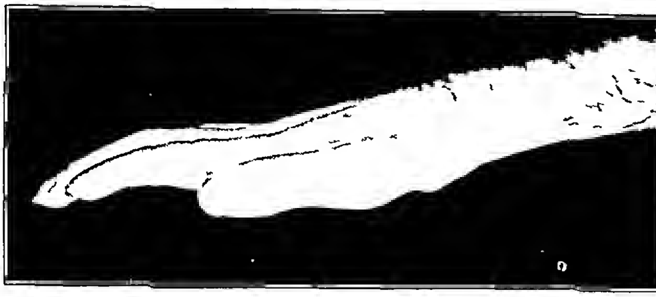

Fig. 4-A

Fig. 4-B

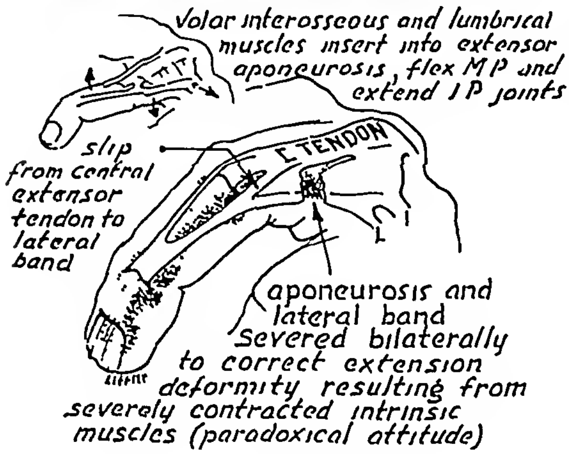

Fig. 4-C

Fig. 4-A. Moderate ischaemic contracture of paralyzed intrinsic muscles prevents hyperextension of metacarpophalangeal joints and enables the long extensors to extend the interphalangeal joints.

Fig. 4-B. Full flexion is prevented by the tight dorsal-extensor mechanism.

Fig. 4-C. When the dorsal-extensor mechanism is so contracted that flexion is greatly impaired, the lateral bands and dorsal aponeurosis can be severed, as shown, through a dorsal mid-line incision over the proximal phalanx. This procedure releases the intrinsic-extensor function, but retains its flexor action at the metacarpophalangeal joint, thus permitting the long extensor to act on the interphalangeal joints.

Fig. 5-A

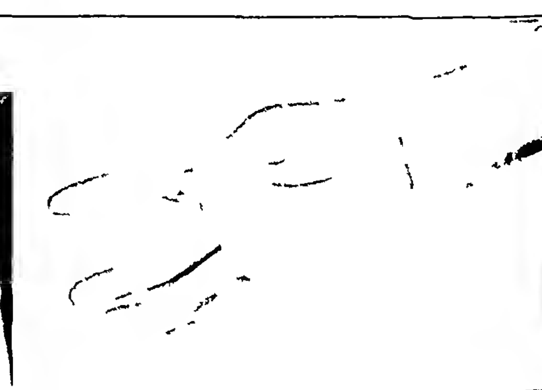

Fig. 5-B

Fig. 5-A. Restoration of function of first dorsal interosseus by transference of extensor pollicis brevis.
Fig. 5-B. Opposition gained by prolonging flexor carpi ulnaris with palmaris longus graft. Lumbricalis interosseous function has been restored by four-way splitting of ring-finger sublimis tendon and transference to dorsal aponeurosis, as illustrated in Fig. 3.

within its fibrous sheath at the wrist. In such cases the sheath must be opened and the tendon displaced to the radial side of the wrist, into the subcutaneous tissue. The transfer for opposition can then be done. A splint should be worn until the transferred tendon has gained sufficient strength and amplitude to maintain the thumb in the functional position.

In most hands the middle and terminal phalanges can be extended by the long extensor tendons, if hyperextension of the metacarpophalangeal joints is prevented.[7] This function is lost when the intrinsic muscles which stabilize the joints are paralyzed. A moderate contracture of the paralyzed lumbricalis interosseous muscles favors hand function in combined median and ulnar nerve injury by stabilizing the metacarpophalangeal joints in partial flexion or by preventing their hyperextension, so that the intact long extensors can act to extend the interphalangeal joints (Figs. 4-A, 4-B, and 4-C). This paradoxical function is simulated by tendon transfers, which serve as a checkrein on exten-

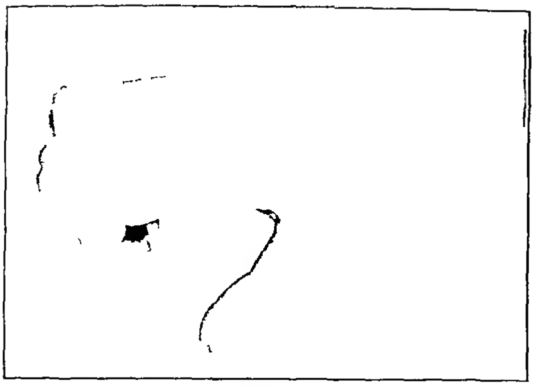

FIG 6-A

Fig 6-A Intrinsic-muscle paralysis with complete loss of proximal and distal interphalangeal-joint extension. Weakened long extensors had no effect on the middle phalanges when the metacarpophalangeal joints were held in flexion

Fig 6-B Opposition was restored by prolongation of the flexor carpi ulnaris with a free graft. Finger extension was gained by prolongation of the detached extensor carpi radialis longus with free tendon grafts (toe extensors) to the dorsal aponeurosis and lateral bands of the fingers, as shown in the sketch. This transferred tendon primarily flexes the metacarpophalangeal joint, but coordinately, when metacarpophalangeal-joint flexion is prevented by the long extensor, the force of the transfer is then exerted toward interphalangeal-joint extension. The wrist had to be fused for stability. Abduction of the index finger was provided by transference of the extensor pollicis brevis to the tendinous insertion of the first dorsal interosseus, and thumb flexion, by a transfer of the main extensor of the little finger to the long flexor of the thumb

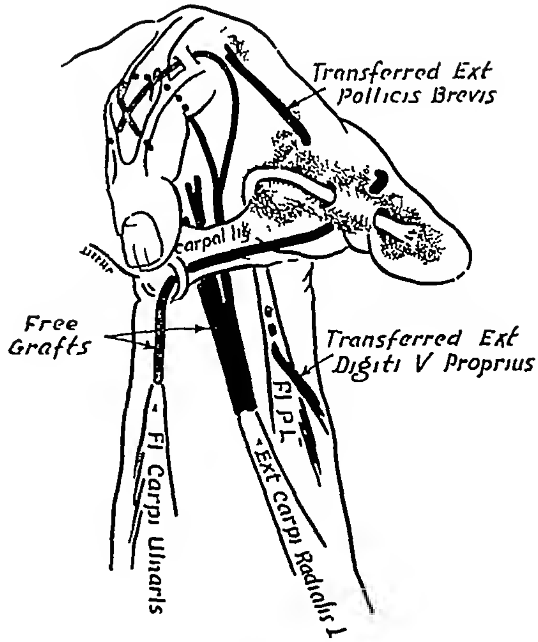

FIG 6-B

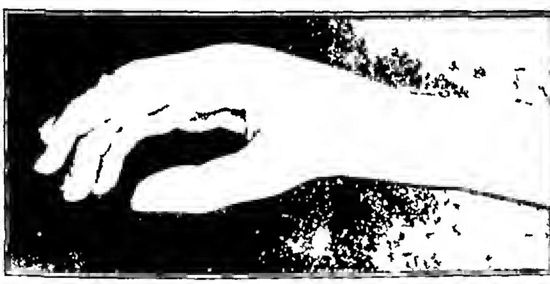

FIG 6-C

FIG 6-D

Final views showing extension and opposition. A strong, useful hand resulted

sion of the metacarpophalangeal joints. Restoration of the lumbricalis interosseous action, metacarpophalangeal-joint flexion, or stabilization and extension of the terminal phalanx of the finger, is gained by splitting into four strands a detached sublimis tendon from either the index finger, middle finger, or ring finger. These strands are passed from the wrist through the lumbrical canals[8] to the dorsal aponeurosis and lateral bands of the fingers, where, with the wrist and metacarpophalangeal joints flexed, they are secured with a running suture of stainless-steel wire (Fig 3). Both the tendon and the aponeurosis are roughened to ensure union. This technique has been fully described by Bunnell.

Abduction of the index finger is restored by a transfer of the extensor pollicis brevis, if well developed, to the tendinous insertion of the paralyzed first dorsal interosseus[1] (Figs 5-A and 5-B). (It would be unwise to sacrifice a sublimis tendon for this transfer[5].) In most cases this transfer is combined with the transfer of the sublimis to the dorsal aponeurosis. In the case of the index finger, when the abductor transfer is done, the sublimis strand is not passed through the lumbrical canal, but is sutured to the lateral band on the ulnar side, where it serves to adduct and flex the metacarpophalangeal joint and to assist in terminal extension (Fig 3). The lateral band on the radial side of the index finger is composed chiefly of the small lumbrical tendon, whereas on the ulnar side it

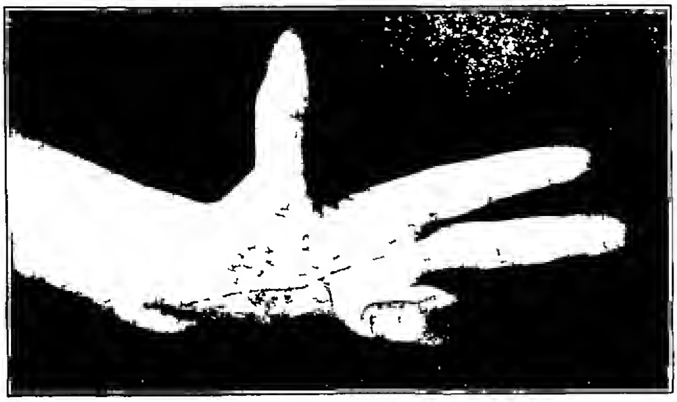

Fig 7-A

Fig 7-A Marked hyperextension of the metacarpophalangeal joint of the thumb, secondary to paralysis of the ulnar innervated intrinsic muscles The palmar injury had destroyed the motor branch of the ulnar nerve Loss of ring finger extension was restored by suturing the severed common extensor tendon to the adjacent intact extensor of the middle finger

Fig 7-B The detached ring-finger sublimis tendon was withdrawn through a palmar incision and was passed transversely beneath the flexor tendons to the insertion of the adductor pollicis muscle

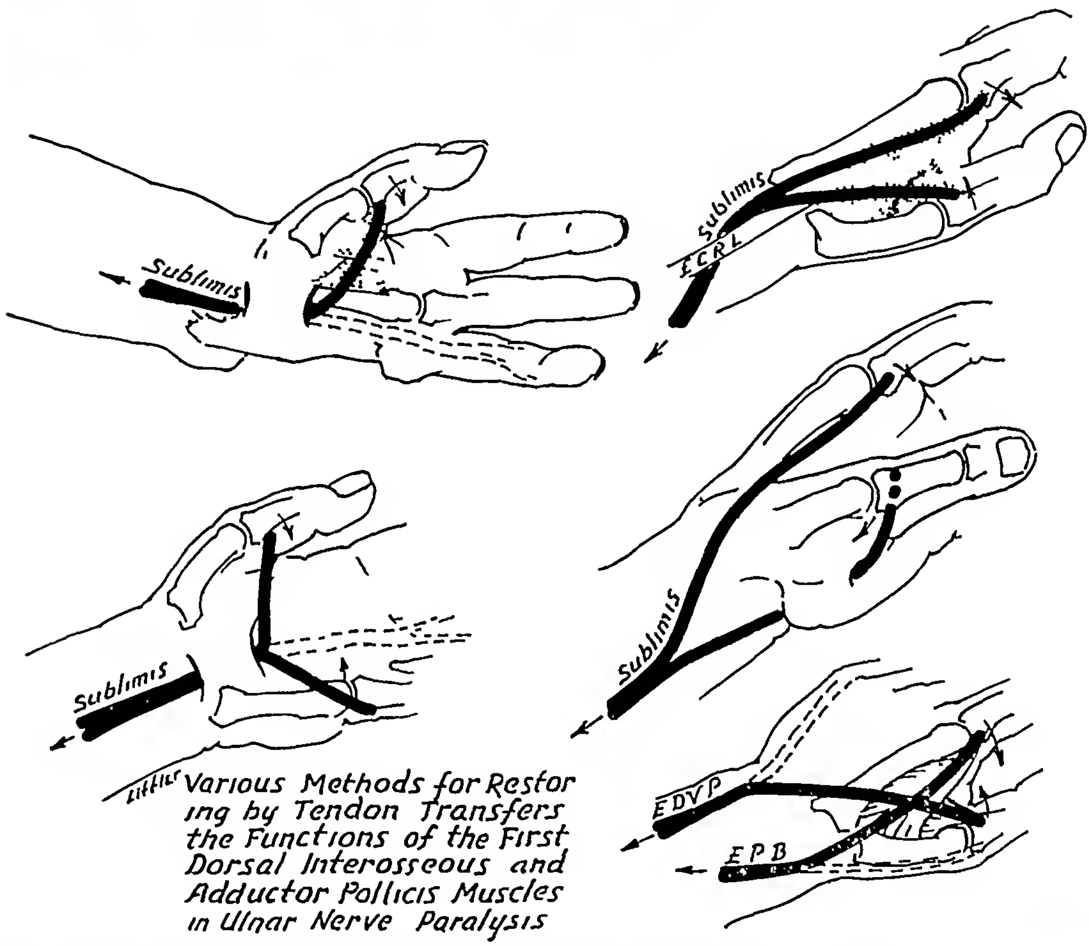

Fig 7-B

E C R L = extensor carpi radialis longus
E D V P = extensor digiti quinti proprius *E P B* = extensor pollicis brevis

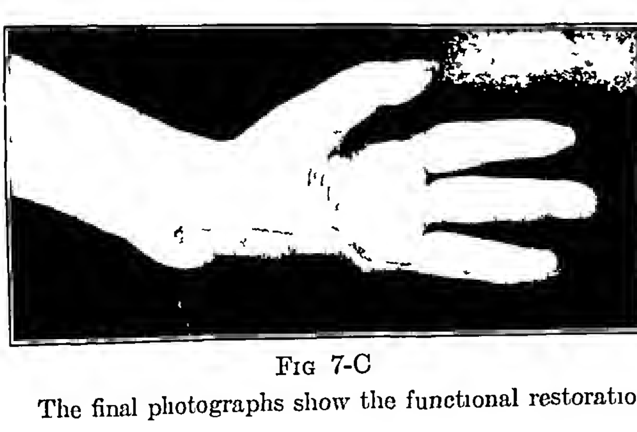

Fig 7-C

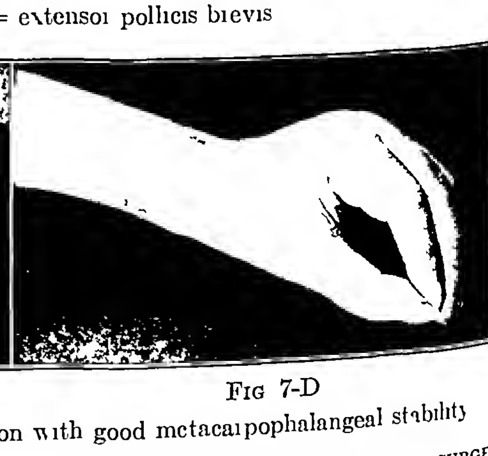

Fig 7-D

The final photographs show the functional restoration with good metacarpophalangeal stability

is formed by the strong volar interosseous tendon[3] and makes a better and more direct attachment for the transferred sublimis

A wrist flexor or extensor tendon can be prolonged with four free grafts to the extensor aponeurosis, if finger strength would be jeopardized by the use of a sublimis tendon, or a paralyzed sublimis can be used by empowering it with an intact extensor tendon Fowler has successfully utilized the main extensor tendons of the index finger and little finger for flexion of the metacarpophalangeal joint

If the middle and terminal phalanges cannot be extended by the long extensors when the metacarpophalangeal joints are stabilized in mid-flexion, a tendon transfer from the volar aspect of the hand to the dorsal aponeurosis and lateral bands of the proximal phalanx will be ineffectual The transferred

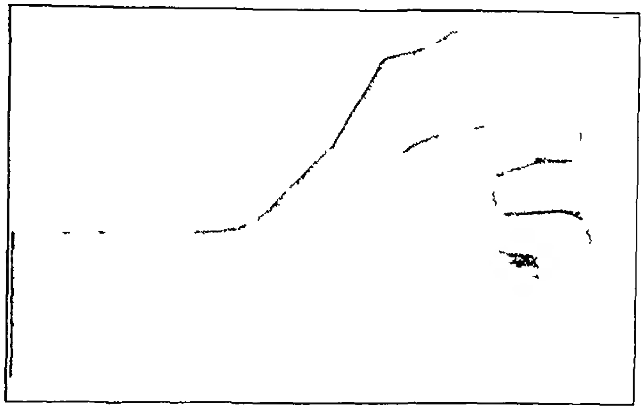

Fig 8-A

Combined median and ulnar nerve paralysis, resulting from a wound involving the brachium Nerve suture provided reactivation of forearm muscles with sensation, but no intrinsic-muscle function

Fig 8-B

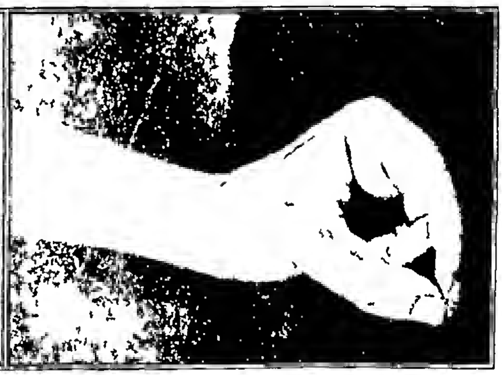

Fig 8-C

Opposition was restored through the flexor carpi ulnaris and a free graft The ring-finger sublimis was split and transferred to the dorsal aponeurosis of each finger Fusion of the metacarpophalangeal joint of the thumb provided stability and corrected the hyperextension Good finger extension, grasp, and pinch were restored

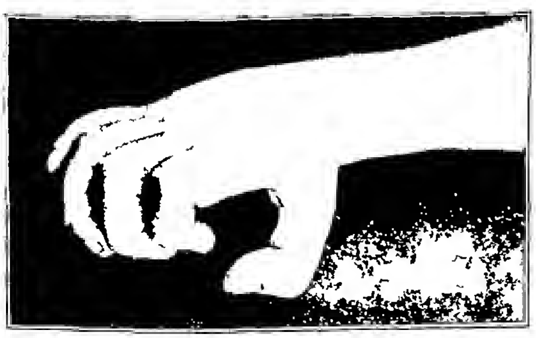

Fig 9-A

Fig 9-B

Fig 9-A Combined median, ulnar, and radial nerve paralysis Good flexion returned after nerve suture, but wrist fusion and transfer of the flexor carpi radialis to the extensor tendons of the thumb and fingers were necessary to compensate for the radial-nerve loss A functionless and anaesthetic little finger was amputated Acute flexion of the terminal phalanges, resulting from intrinsic-muscle paralysis and flexor imbalance, impaired function

Fig 9-B By fusion of the distal joints of the thumb and index finger in the pinch position, a useful hand was obtained

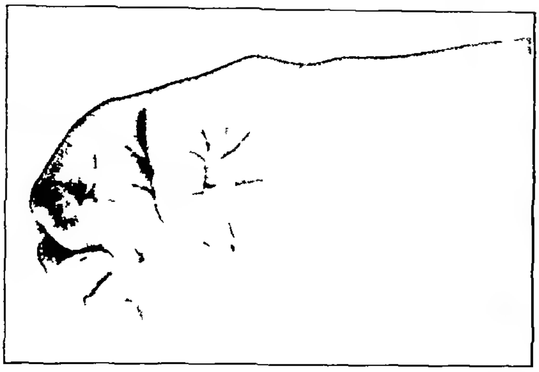

FIG 10-A

FIG 10-B

Fig 10-A Total loss of flexor function and paralysis of intrinsic muscles resulted from a gross destructive wound of the forearm The median and ulnar nerves were approximated and a fair degree of sensation was restored to the hand A wrist fusion made active extensor tendons available for flexion of thumb and fingers, but the poor position of the thumb made the hand useless

Fig 10-B By fusion of the carpometacarpal and the interphalangeal joints, a useful thumb in good position was obtained

FIG 11-A

Fig 11-A Permanent fixation of the first metacarpal in the position of optimum usefulness by an intermetacarpal strut of tibial bone

Fig 11-B Sketch illustrating the architectural principles involved in placing the bone strut between the first and second metacarpals

1 The first metacarpal is held at an angle of 90 degrees to the palmar plane, and may be rotated from 30 to 45 degrees on its longitudinal axis

2 An angle of 45 degrees is obtained between the two metacarpals at the carpus

3 Lateral placement of the strut rotates the first metacarpal

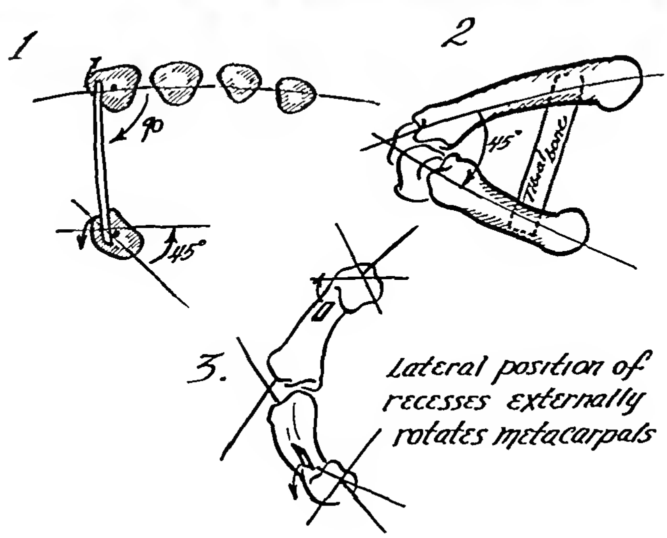

FIG 11-B

tendon will have to be carried from each side of the finger over the dorsal apex of the proximal interphalangeal joint into the converging lateral bands of the middle phalanx, according to the method of Fowler (Figs 6-A to 6-D) Full passive extension of the proximal interphalangeal joint is imperative, if the transfer is to be successful A metal splint to hold the wrist and metacarpophalangeal joints flexed and the interphalangeal joints extended will greatly facilitate the suturing

If an additional sublimis tendon can be spared, the palmar and thumb arches can be restored by suturing one division of the detached tendon to the adductor pollicis insertion and the other division to the base of the proximal phalanx of the little finger on its ulnar aspect, or the entire tendon may be sutured only to the adductor pollicis insertion The former procedure simulates the tendon T operation described by Bunnell, and is used when both arches are to be restored, the latter procedure is used in patients having marked

hyperextension of the metacarpophalangeal joint of the thumb (Figs 7-A to 7-D)

The arch of the thumb is maintained by the long abductor, the adductor, and short flexors, which prevent hyperextension of the metacarpophalangeal joint If the joint is hyperextended when the adductor and flexor pollicis muscles are paralyzed, the terminal phalanx is pulled into flexion by the flexor pollicis longus (Froment's sign), and in time an irreversible flexion contracture of the interphalangeal joint may result, greatly impairing opposition When the interphalangeal joint cannot be extended passively, or if the long thumb extensor cannot extend the terminal phalanx when the metacarpophalangeal joint is stabilized, a fusion of the interphalangeal joint at 15 to 30 degrees of flexion or extension (the latter only if pulp atrophy is severe) will permit useful opposition of the thumb to the fingers When the interphalangeal joint has been fused, the flexor pollicis longus flexes the metacarpophalangeal joint If the flexed terminal phalanx can be extended by the long extensor when the metacarpophalangeal joint is stabilized, and no tendon is available for transfer, a fusion of this joint at 20 degrees of flexion and 10 degrees of pronation will make possible active extension of the terminal phalanx and greatly improve opposition (Figs

Fig 12-A

Destruction of forearm muscles and of median and ulnar nerves resulted in total loss of useful hand function Sensation was restored through nerve suture

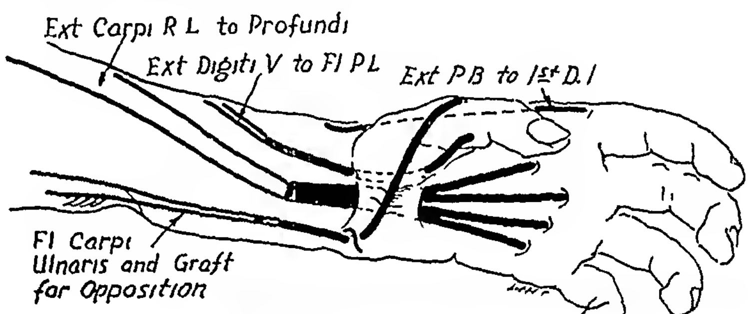

Fig 12-B

Fig 12-B Finger flexion, thumb flexion and opposition, and index-finger abduction were restored by tendon transfers, as illustrated in sketch

Figs 12-C, 12-D, and 12-E Despite the loss of intrinsic-muscle function, the fingers fortunately did not claw and a good functional result was obtained

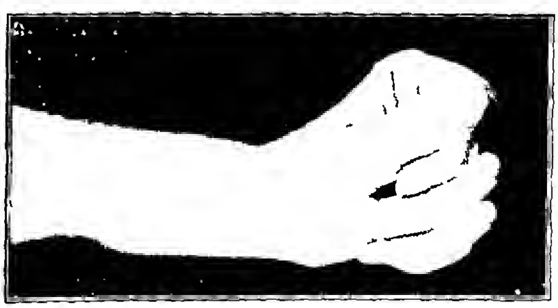

Fig 12-C

Fig 12-D

Fig 12-E

8-A, 8-B, and 8-C). A tendon transfer for opposition may rotate the thumb metacarpal and the proximal phalanx into good position, but, if the terminal phalanx remains acutely flexed, pulp opposition is not attained (Figs. 9-A and 9-B).

Amputation through the interphalangeal joints of the thumb and fingers is sometimes necessary to eliminate the acutely flexed and atrophic terminal phalanges. This provides a fully rounded finger tip and eliminates the added complexity of interphalangeal function. When an adducted thumb cannot be mobilized sufficiently by a tendon transfer, a functional position can be obtained either by fusion of the carpometacarpal joint (Figs. 10-A and 10-B) or by bridging of the first intermetacarpal space with a bone graft (Figs. 11-A and 11-B). Temporary joint stabilizations are sometimes useful in maintaining good position until tendon transfers are functioning or until some deformity has been corrected. A Kirschner wire passed through a joint will maintain position for long periods of time, but, after removal, function will again be possible.

Volitional control of transferred tendons is readily gained if the innervation of their muscles is unimpaired. Paralyzed muscles which have regained function following nerve suture often lack the highly individualized control and strength desirable for successful transfers. It is frequently necessary, however, to use such a muscle for transfer in combined median and ulnar nerve injuries, but the results may be good, especially if only an automatic checkrein effect is required to prevent hyperextension of the metacarpophalangeal joints. The stretch reflex seems to have some bearing on the re-education of transferred tendons. Following the three-week period of immobilization after operation, the patient must be trained carefully in the use of the transfers. He must know what previous function has been altered, and his efforts must be directed toward volitional and synergistic control of the transferred tendons.

CONCLUSIONS

Residuals of a single-nerve injury, manifested by paralysis and muscle imbalance, are readily compensated for by appropriate tendon transfers. The procedure becomes complicated when any two nerves are involved. Correct evaluation of the partially paralyzed hand must be made and available tendon power must be concentrated where it will be effective in restoring useful function. Proper arthrodeses will provide stabilization and make additional power available for transfer. Not infrequently it is necessary to fuse the wrist or the thumb, or both, in a position of function, and to transfer wrist-extensor tendons, if a good pinch and grasping mechanism is to be gained. In badly crippled hands only a pinch mechanism may be possible, but to that end we should concentrate our effort; if we attempt more, potential power may be dissipated and a useless hand will result.

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SURGICAL APPROACHES TO THE SHOULDER JOINT *

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The shoulder joint is a complex mechanism consisting of the sternoclavicular, the acromioclavicular, and the scapulohumeral joints, together with the virtual joint between the scapula and the thoracic cage. Contrary to traditional teaching, elevation of the arm is accomplished by movement occurring simultaneously in the several joints, acting as a single unit to produce that smoothness of motion aptly termed "scapulohumeral rhythm". Operations upon any of the joints of the complex must be planned with the idea of minimum interference with their gliding surfaces and with the ligaments and muscles which support and control their movements. For example, ankylosis resulting from an operation on the acromioclavicular joint permanently disturbs the rhythm and reduces the range of motion in the shoulder as a whole. Therefore, there are two features which demand major consideration from the surgeon. The first of these is a realization of the functional and dynamic aspects of the shoulder complex. The second is an accurate anatomical knowledge which will enable him to carry out the contemplated procedure with the least possible disturbance of function. Although these joints operate as a unit, the surgical approaches to each one should be considered separately.

THE STERNOCLAVICULAR JOINT

Surgical Anatomy

The sternoclavicular joint is established by the articulation of the medial end of the clavicle with the clavicular notch of the manubrium sterni and the superior surface of the first costal cartilage. The bony surfaces of the articulation are separated by an intra-articular fibrocartilaginous disc, and the entire joint is isolated by a capsule, reinforced in front and behind by the anterior and posterior sternoclavicular ligaments, of which the posterior is by far the more substantial. The joint is strengthened by two accessory ligaments, the interclavicular and the costoclavicular. The interclavicular ligament is attached to the rough, upper portion of the medial end of the clavicle on each side, blends with the superior portion of the capsular ligament, and is adherent at its middle to the center of the suprasternal notch. The strong, short, costoclavicular ligament passes from the costochondral junction of the first rib to be attached to the tubercle on the inferior aspect of the clavicle, near its medial end (Fig. 1).

Functionally, the joint permits elevation and depression of the clavicle with the corresponding movements of the arm, forward and backward movements with retraction and protraction of the shoulder, as well as circumduction. In addition, the sternoclavicular joint, together with the acromioclavicular, permits rotation of the clavicle about its long axis during elevation of the extremity. All these movements, with the exception of the backward and forward motions, occur in the lateral compartment of the joint between the disc and the clavicle.

Two features of the joint are of special importance to the surgeon. First, it should be recognized that the integrity of the joint is dependent in greatest measure upon the accessory ligaments, notably the costoclavicular. Second, the relations of the joint, especially the intimacy of the great veins of the neck to the posterior aspect and the close relationship of the pleura, must be borne in mind. The first point is of significance in the

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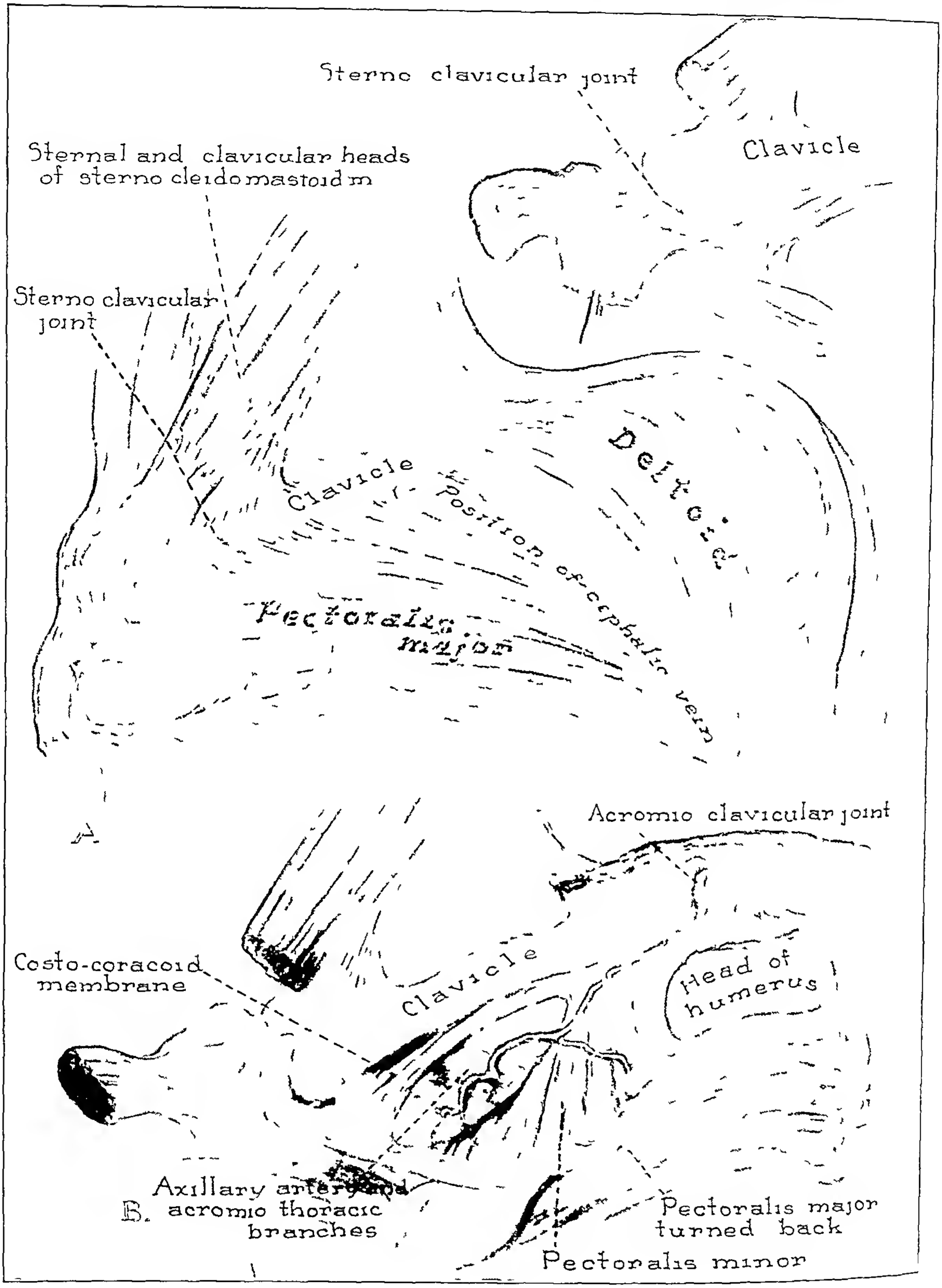

FIG 1

Dissections to show anatomical relationship of the sternoclavicular and acromioclavicular joints

A The clavicle and the cephalic vein, lying between adjacent borders of the pectoralis major and deltoid, and the relationship of the sternoclavicular joint to the sternal and clavicular heads of the sternocleidomastoid

B The acromioclavicular joint, the pectoral muscles, and the costocoracoid membrane

C The sternoclavicular joint

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mechanism of dislocation and establishes the principles for its repair, and the second constitutes hazards in operative approaches

Therefore, the important structures on the anterior and superior aspects of this joint are the upper fibers of the pectoralis major, the sternal head of the sternocleidomastoid, and, in close proximity, the clavicular head of the same muscle with the anterior and external jugular veins disappearing beneath the medial and lateral borders of the muscle, respectively. Posterior to the medial inch of the clavicle are the attachments of the sternohyoid and sternothyroid muscles, which separate the bone from the innominate vein, phrenic nerve, internal mammary artery, pleura, and lung from before backward. The right joint is related posteriorly to the innominate artery, in addition. The left joint is in especially close relationship to the innominate vein,—so much so that the vein may be adherent to it and, with careless manipulations, there may be danger of damage to its walls, producing hemorrhage or thrombosis.

Approaches to the Sternoclavicular Joint

A. *Indications.* The indications are:

(1) recurrent and disabling dislocation of the joint;

(2) infection requiring drainage; and

(3) tumors involving the joint.

B. *Position of the Patient.* The patient is supine with a small sandbag placed between the shoulder blades.

C. *Incision.* A straight or curved incision is made through the skin, exposing the capsule of the joint and the two heads of the sternocleidomastoid. The joint surfaces are then exposed by curved division of the capsule and by subperiosteal reflection of the heads of the sternocleidomastoid. Through this approach the joint can be inspected thoroughly. When tumors involve this joint, a more extensive dissection may be required, with ligation of the anterior and external jugular veins.

THE ACROMIOCLAVICULAR JOINT

The acromioclavicular joint is the diarthrosis occurring between the lateral end of the clavicle and the anteromedial margin of the acromion (Fig. 1). The opposed articular surfaces lie in an oblique plane which passes downward and medially. The weak capsule, thickened above and below, contains a wedge-shaped articular disc which protrudes into the joint cavity from the upper portion of the capsule. The joint is strengthened by an accessory ligament, the coracoclavicular, which extends from the upper surface of the coracoid process to the inferior aspect of the lateral end of the clavicle. The coracoclavicular ligament consists of two portions: the trapezoid ligament, lying anterolaterally and attached to the trapezoid ridge of the clavicle, and the conoid ligament, placed posteromedially and affixed to the conoid tubercle at the apex or summit of the curvature in the lateral third of the clavicle. The interval between the two segments is occupied by a bursa, which lessens the friction between them during motion. The coracoclavicular ligament constitutes the important structural support of the acromioclavicular joint and, apart from muscles, the entire upper extremity is suspended from it. Dislocation of the acromioclavicular joint cannot occur without damage in greater or less degree to this accessory ligament, surgical repair of which is often necessary when the dislocation is complete.

Functionally, slight gliding movements in various directions are permitted at the acromioclavicular joint, which serve to maintain an unchanged relationship between the glenoid cavity of the scapula over the head of the humerus in all positions of the extremity. However, of far greater importance is the rotation of the clavicle about its long axis during elevation of the extremity. This rotation, amounting to approximately 45 degrees, enables the curved outer end of the clavicle to act as a crankshaft. Since the coracoclavicular ligament is attached to the apex of this crank, these structures undergo relative elongation during elevation which, in turn, permits the complete rotation of the scapula. Interruption

of this movement of clavicular rotation immediately limits active abduction to about 90 degrees, although the extremity can be carried passively to about 110 degrees Furthermore, in reconstructing the coracoclavicular ligament by the fascia lata or other material, the new ligament should, in order to preserve the functional mechanism, be attached to the clavicle well posteriorly, at the apex of the lateral curve or along the trapezoid line Otherwise, some restriction of motion can be anticipated

Approaches to the Acromioclavicular Joint

A *Indications* The indications are
(1) acromioclavicular dislocations,
(2) fractures involving the joint,
(3) infections, and
(4) arthritis

B *Position of the Patient* The patient is in a sitting position, with the shoulder extending well beyond the edge of the table and with the arm at the side

C *Incision* For repair of the coracoclavicular ligament, an extensive exposure is generally required, such as is described by Roberts Beginning at the angle of the acromion, an incision is made over its lateral and anterior margins, thence across the acromioclavicular joint and along the anterior surface of the lateral one-third of the clavicle, from here it turns downward and outward to follow the groove between the pectoralis major and deltoid muscles Here, the coracoid process is a valuable guide, since it lies one inch below the junction of the middle and lateral thirds of the clavicle, where it is covered by the inner margin of the deltoid By the separation of the pectoralis major and deltoid, the cephalic vein is revealed as it passes obliquely upward and backward to pierce the costocoracoid membrane, where it joins the axillary vein The vein should be preserved within its sheath, and retracted medially with a thin section of the deltoid Following this, the origin of the deltoid is detached from the clavicle with a thin shaving of bone This produces less bleeding than when a strictly subperiosteal detachment is made In order to permit reflection of the origin of the deltoid laterally, the deltoid branches of the acromiothoracic axis are ligated The coracoid process is then exposed, and on it may be seen the insertion of the pectoralis minor and the combined origin of the short head of the biceps and the coracobrachialis The repair of the coracoclavicular ligament may be accomplished by any one of a variety of techniques, such as those employed by Bunnell, Bankart, or Lowman

THE SCAPULOHUMERAL JOINT

Surgical Anatomy

The scapulohumeral joint is established by the articulation of the large hemispherical surface at the humeral head with the comparatively small and slightly concave surface of the glenoid cavity of the scapula The glenoid is deepened and enlarged by the presence of the labrum glenoidale or so-called glenoid ligament, a ring of fibrocartilaginous tissue triangular in section, attached to the periphery of the cavity The joint is strengthened above by the so-called "arch of the shoulder", formed by the coracoid process, the acromion, and the coraco-acromial ligament The capsule, exceedingly lax, is attached proximally to the labrum and the rim of the glenoid cavity, blending directly above with the intra-articular attachment to the long head of the biceps, distally it encircles the head and is fused superiorly with the anatomical neck of the humerus, but inferomedially it extends on to the surgical neck, about half an inch below the head The capsule is reinforced superiorly by the coracohumeral ligament, morphologically a continuation of the tendon of the pectoralis minor, and anteriorly by the three ill-defined glenohumeral ligaments The anterior aspect of the capsule presents a deficiency of varying size, through which is herniated a portion of the synovial lining of the joint to establish the subscapularis bursa

The long head of the biceps arises within the joint from the supraglenoid tubercle and blends with the labrum glenoidale. It traverses the joint, resting on the upper surface of the head of the humerus, to reach the intertubercular groove. The intra-articular portion of the tendon is surrounded by synovial membrane, which is carried by the tendon for some distance beyond the capsular attachment to form a second synovial herniation. The tendon is held in position by means of the transverse humeral ligament, an insignificant structure roofing the intertubercular groove. Maintenance of the tendon in its groove is dependent in large measure on the thickening of the lateral margin of the capsule, where it bridges the interval between the greater and lesser tubercles, and on the tendon of the pectoralis major, as it passes laterally to its insertion on the lateral lip of the groove. Consequently, dislocation of the tendon can occur only in the medial direction. Functionally, the humerus glides on the tendon during motion for a distance of almost an inch, and the synovial pouch permits this to occur without friction. The presence of an adhesive tendinitis, therefore, not only limits motion, but, by pulling upon adhesions, results in the production of pain.

The structures in immediate relationship to the joint are the short rotator muscles. Active support to the anterior aspect of the joint is afforded by the tendon of the subscapularis, inserted into the lesser tuberosity of the humerus and separated from the capsule by the subscapularis bursa. Superiorly is the tendon of the supraspinatus, and posteriorly the tendons of the infraspinatus and teres minor. These muscles insert, from before backward in the order named, into the greater tuberosity of the humerus. The inferior aspect of the joint is unsupported and lies in relationship to the so-called quadrilateral space. The tendons of the four muscles mentioned blend with one another as a musculotendinous cuff which, in a sense, constitutes a partial secondary capsule for the joint. Between the musculotendinous cuff and the capsule exists a small quantity of areolar tissue, which serves as a gliding plane during muscular activity. The great importance of the musculotendinous cuff in maintaining the integrity of the joint should be borne in mind constantly. Furthermore, these short muscles, especially those lying on the anterior and posterior aspects, constitute one of the essential components of the force couple, which is the essential mechanism for active elevation of the arm. The deltoid alone is incapable of abducting the humerus without the interaction of these small muscles.

The deltoid hangs like a curtain from the overlying acromial arch, covering the anterior, lateral, and posterior aspects of the joint. It arises from the lateral third of the clavicle, the lateral border of the acromion, and the inferior border of the spine of the scapula, to insert into the deltoid tubercle on the middle of the lateral border of the shaft of the humerus (Fig. 3). Four features of importance present themselves to the surgeon in connection with this muscle. First, the origin of the muscle extends for some distance on the superior aspect of the bones, from which it arises in the form of tendinous fibers. These fibers, by blending with the periosteum, permit surgical detachment of the muscular origin with a considerable border of connective tissue, which readily permits reattachment without undue tension on the sutures. Second, in close relationship to the muscle origin and beneath it lie a group of vessels following the origin circumferentially which, if sought for and ligated in the region of the anterior portion of the muscle, permit detachment with little or no hemorrhage. Third, the region of the muscle lying approximately opposite the tip of the acromion process presents a tendinous interval, an inch and a half to two inches in length, which enables the surgeon to split the muscle at this point through a relatively bloodless field. A fourth feature of importance is the precise relationship of the axillary nerve, which will be discussed later.

Beneath the deltoid lies the subdeltoid or subacromial bursa. This bursa is very extensive and not only lies between the deltoid muscle and the greater tubercle of the humerus, but extends beneath the acromial arch and the coraco-acromial ligament above the joint as far medially as the root of the coracoid process. In floor therefo

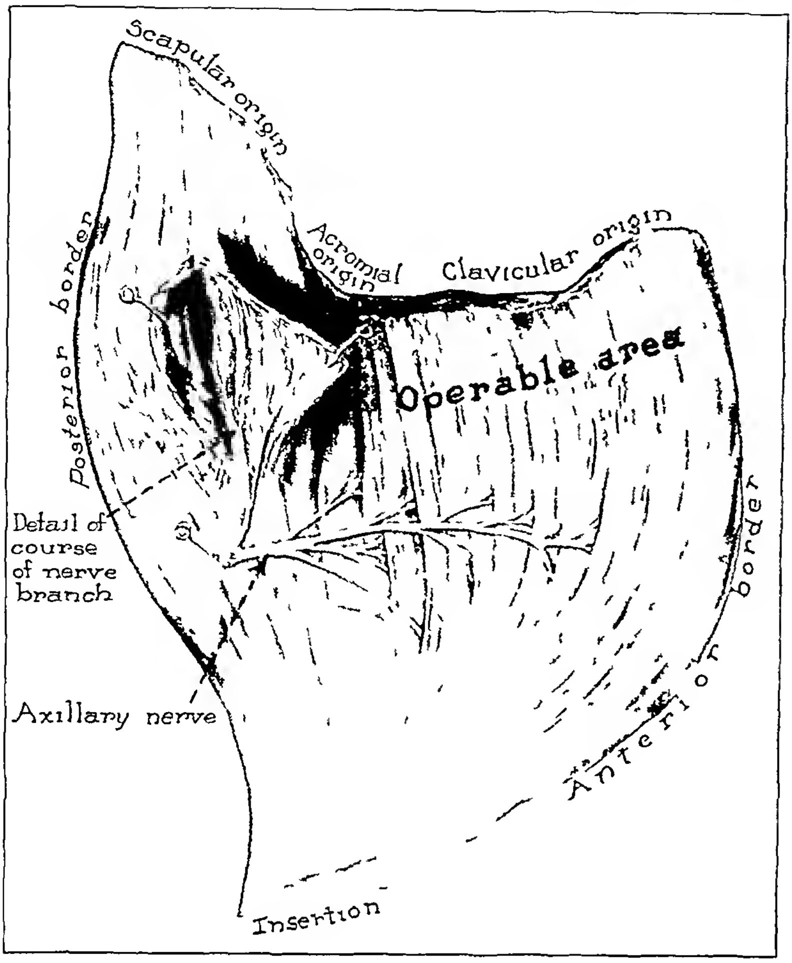

FIG 2

Dissection of the inner aspect of the left deltoid, demonstrating the location of the axillary nerve The course of the nerve lies about two inches below the origin of the muscle Detail of one branch shows that muscle-splitting incisions, even in the operable area, do some damage to the innervation

musculotendinous cuff, the tubercles of the humerus, and the intertubercular sulcus An excellent description of the detailed arrangement of this bursa is to be found in Codman's book, *The Shoulder*

The pectoralis major, arising from the medial portion of the clavicle, the anterior aspect of the sternum, the upper ribs, and the aponeurosis of the external oblique, is inserted by means of a flat, bilaminar tendon into the lateral lip of the intertubercular groove The clavicular head passes anterior to the sternocostal head to insert more distally and blend with the tendinous insertion of the deltoid The upper sternocostal fibers run under cover of the clavicular portion and fuse with the deep surface of its tendon The lower sternocostal fibers and those arising from the aponeurosis curve upward behind the upper sternocostal fibers, to extend beyond their insertion as a fascial expansion, which stretches over the biceps tendon to blend with the capsule of the shoulder joint

The cephalic vein lies in the deltopectoral groove, formed by the adjoining margins of the deltoid and pectoralis major, respectively Here the vein is associated with tributaries from neighboring structures and, as it passes upward, it occupies a progressively deeper level, eventually piercing the costocoracoid membrane to join the axillary vein The cephalic vein is, therefore, a useful guide to the axillary vessels

Under cover of the anterior border of the deltoid lies the coracoid process, from which the coracobrachialis and short head of the biceps arise and into which the pectoralis minor is inserted The former muscles, therefore, have a close anterior relationship with the joint, and the tendon of the pectoralis minor is frequently exposed in operative approaches Medial to the coracobrachialis lie important branches of the brachial plexus and the great vessels, therefore, exploration on the medial side of this muscle should be undertaken with especial care

Postero-inferiorly are the tendons of the latissimus dorsi and the teres major, forming the posterior wall of the axillary space The tendon of the latissimus dorsi winds around that of the teres major to insert into the floor of the intertubercular groove, whereas the teres major inserts into its medial lip

On the inferior aspect, bounded laterally by the shaft of the humerus, below by the teres major, medially by the long head of the triceps arising from the infraglenoid tubercle and above by the subscapularis, capsule of the shoulder joint, and teres minor, is the

quadrilateral space, through which pass the axillary nerve and the posterior circumflex humeral artery.

The surgeon should recall the position of the transverse scapular artery and suprascapular nerve as they lie superomedial to the joint. The nerve passes through the suprascapular notch, medial to the coracoid process and the artery immediately above it. Both enter the supraspinous fossa and, having supplied the muscle contained therein, wind around the root of the spine through the greater scapular notch to reach the infraspinous fossa, terminating in the infraspinatus muscle. These structures are endangered in tears of the musculotendinous cuff, if the divided tendon is sought for too deeply and carelessly.

Nerves about the Shoulder

In surgical approaches to the shoulder joint, the axillary nerve occupies a position of supreme importance. It arises from the posterior cord of the brachial plexus, posterior to the great vessels, and, as it descends, it passes inferior to the capsule of the shoulder joint through the quadrilateral space. Here it divides into posterior and anterior divisions. The posterior division supplies motor branches to the teres minor and the posterior third of the deltoid muscle. From it is derived the lateral cutaneous nerve of the arm, which winds around the posterior border of the deltoid, accompanied by a small vessel to supply the skin over the upper lateral aspect of the deltoid. In posterior approaches, isolation of this small cutaneous nerve, readily recognized owing to the presence of the accompanying vessel, enables the surgeon, by following it more deeply, to recognize the main trunk of the nerve. The anterior division proceeds around the surgical neck of the humerus, accompanied by the posterior circumflex artery. In relationship to the surface, the nerve occupies a position a little above the mid-point between the lateral margin of the acromion process and the insertion of the deltoid. The anterior division supplies the anterior two thirds of the deltoid, and its protection is of the greatest importance in superolateral approaches to the joint. Its muscular twigs are given off at intervals, to pass vertically upward. Therefore, incisions which are made with separation of the fibers of the deltoid should not extend downward for more than one and one-half inches below the margin of the acromion process, otherwise some weakness of the deltoid can be anticipated (Figs. 2 and 3).

Other important nerves in this area are well described in standard textbooks. They are the suprascapular nerve to the supraspinatus and infraspinatus, the musculocutaneous nerve to the biceps, coracobrachialis, and brachialis, the lateral and medial anterior thoracic nerves to the pectoralis major and minor, the upper, middle, and lower subscapular nerves to the teres major, subscapularis, and latissimus dorsi, and the radial nerve to the triceps. All are derived from the cords of the brachial plexus, which surround the great vessels in the axilla.

Arteries

The arteries of importance in approaches to the shoulder are the transverse scapular, derived from the thyrocervical trunk, and branches from the axillary artery,—namely, the thoraco-acromial and the anterior and posterior circumflex humeral vessels. The transverse scapular artery arises from the thyrocervical artery at the base of the neck and passes directly laterally. We are concerned with it only as it passes above the suprascapular notch, lying in close relationship to the suprascapular nerve, and as it passes around the spine of the scapula to the infraspinous fossa, where it may be subject to surgical injury. The anterior humeral circumflex artery arises from the axillary artery at the lower border of the subscapularis and, having passed behind the origin of the coracobrachialis and the short head of the biceps, is found beneath the deltoid on the surgical neck of the humerus. Here it divides into ascending and descending branches. The posterior humeral circumflex artery, a far more substantial vessel, arises likewise from the axillary artery at about the same level as the anterior. It passes posteriorly through the quadrilateral space, accom-

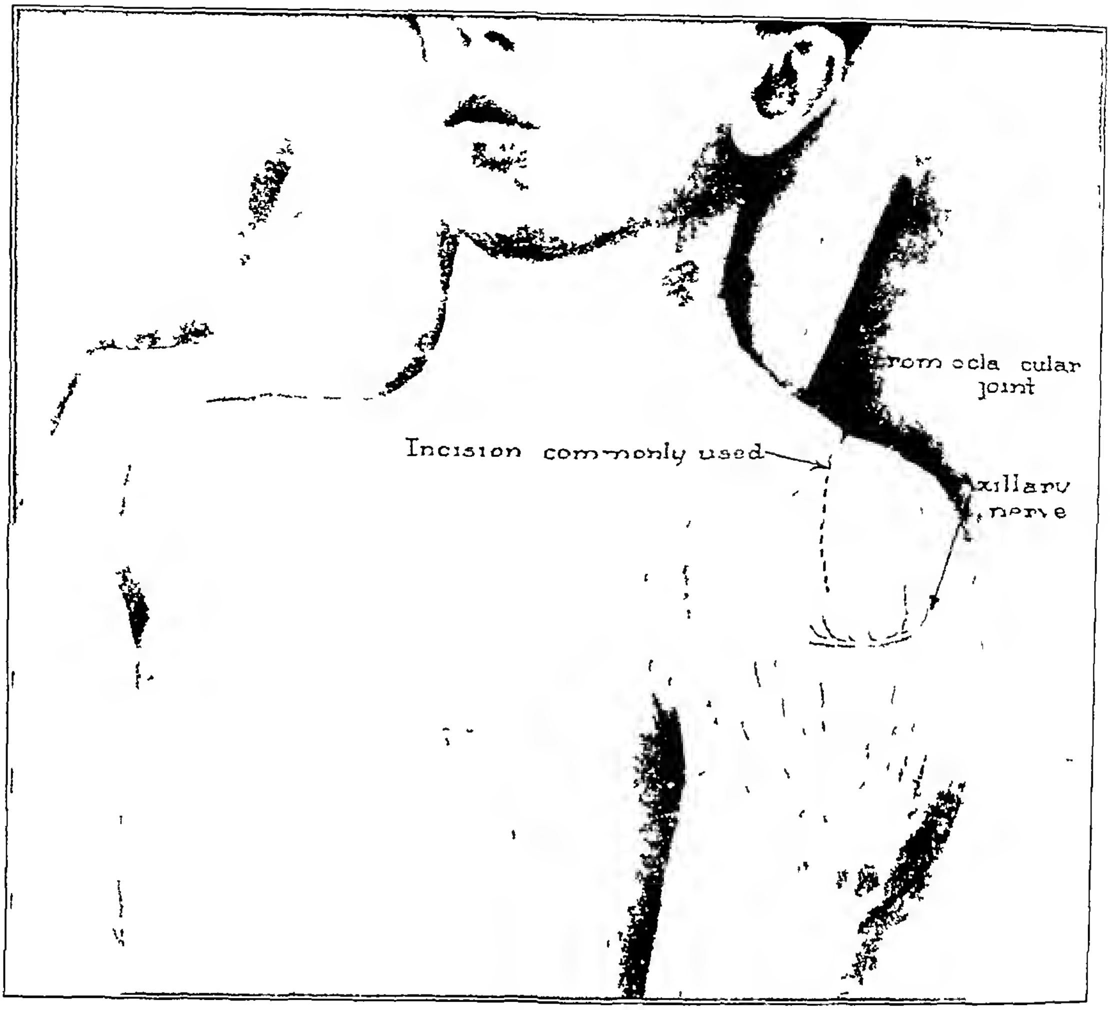

FIG 3

The sitting position, with the shoulder projecting well beyond the border of the operating table This position greatly facilitates the surgical exposure of the anterosuperior and superolateral aspects of the scapulohumeral joint, the subacromial bursa, and the musculotendinous cuff Note position of the axillary nerve in relation to incisions which separate the fibers of the deltoid (Reproduced, by permission of Appleton-Century-Crofts, Inc, from chapter by LeRoy C Abbott, M D, to appear in *Operative Technic*, edited by Warren H Cole, M D)

panying the axillary nerve to wind around the surgical neck of the humerus and distribute branches to the deep surface of the overlying deltoid muscle

The thoraco-acromial artery, a short trunk, arises from the second part of the axillary artery and winds around the upper border of the pectoralis minor to pierce the costocoracoid membrane, where it divides into numerous branches A clavicular branch passes upward towards the clavicle Several large pectoral branches proceed downward between the two pectoral muscles, where they anastomose with the lateral thoracic and lateral branches of the intercostal vessels The acromial branch runs laterally beneath the tendon of the pectoralis minor or above it, frequently supplying twigs to the deltoid This branch is often found on the inferior aspect of the coracoid process, where it may prove troublesome in dissections in the neighborhood of that structure A final branch, the deltoid ramus, takes origin from the common trunk and runs distally in the intermuscular interval between the pectoralis major and the deltoid

SURGICAL APPROACHES TO THE SCAPULOHUMERAL JOINT

The surgical exposure of the scapulohumeral joint is difficult, because of the special anatomical relation of the structures which surround it On the anterior, lateral, and posterior surfaces, the joint is shrouded by the deltoid To avoid permanent damage to this muscle, incisions which pass through it must be made parallel to the direction of its fibers

They should be limited in their extent to an area between the margins of the acromion and the axillary nerve, where it passes from back to front around the upper portion of the shaft of the humerus (Fig. 2). On its superior surface the joint is covered by the protective bony and ligamentous arch formed by the coracoid, the acromion process, and the coraco-acromial ligament. This arch is anchored in position anteriorly by the outer end of the clavicle, articulating with the acromion process to form the acromioclavicular joint. The medial and lateral margins of the outer portion of the clavicle, the acromion, and the spine of the scapula provide attachments for the trapezius and deltoid, respectively. Full access to this part of the joint may require osteotomy of the acromion process, or subperiosteal detachment of the origin of the deltoid from the outer third of the clavicle and the adjoining borders of the acromion.

Exposure of the anterior aspect of the joint is generally obtained by separation of the adjacent margins of the pectoralis major and the deltoid, but in many instances this approach is unsatisfactory unless it is enlarged by separating the origin of the deltoid from the clavicle. In a similar manner, the posterior aspect of the scapulohumeral joint can be disclosed in its entirety by osteotomy of the acromion, or by detachment subperiosteally of the deltoid from the spine of the scapula and the lateral margin of the acromion process.

It can now be seen clearly that complete exposure of the anterior, superior, lateral, and posterior aspects of the scapulohumeral joint can be secured by a curvilinear skin incision which follows the anterior margin of the deltoid and its line of origin from the clavicle, acromion, and spine of the scapula. This permits the origin of the deltoid to be reflected subperiosteally from the clavicle, the inferior margin of the spine of the scapula, and the superior surface of the acromion process. The remainder of the deltoid attachment to the acromion is freed by osteotomy of its lateral border. This method of detaching the deltoid, with an edging of periosteum and bone, provides for adequate repair with sound healing. A segment of this curvilinear incision may be utilized for exposure of one or more aspects of the scapulohumeral joint. Therefore, this incision might appropriately be termed the "comprehensive" incision for exposure of the scapulohumeral joint (Fig. 5).

The Sitting Position for Operations upon the Shoulder

In operations upon the shoulder, the selection of the proper position of the patient and its maintenance throughout the entire operation is of great importance. The surgeon must work with the part supported and held in such a way as to provide easy access to the structures which he wishes to expose. He should not be handicapped by a faulty position of the patient on the operating table. The authors have found that the supine position in operations upon the shoulder does not provide adequate access to its superior, posterior, and lateral aspects. Also, under these conditions, the surgeon works in an awkward and uncomfortable posture which produces both mental and physical fatigue. These difficulties can be obviated by the use of the sitting position (Fig. 3). The authors first used this method of procedure in 1925, in the St. Louis unit of the Shriners' Hospital for Crippled Children. It was found invaluable in arthrodesis of the shoulder for patients disabled by residual paralysis due to anterior poliomyelitis. Only in this way could we accurately palpate the bony landmarks which enabled us to secure the optimum position for function.

From that time on, we extended the use of the sitting position to include practically all operations on the scapulohumeral joint. It is particularly successful in removal of calcified deposits in the musculotendinous cuff, in rupture of the supraspinatus, recurrent dislocation of the shoulder, and fractures of the head and neck of the humerus and its tuberosities. It has also proved of great advantage in operations on the brachial plexus and for the removal of a cervical rib.

Experience has shown that the preferred position is with the trunk at approximately 70 degrees with the horizontal plane, the shoulder extended well beyond the margin of the table, the head turned to the opposite side, and the sterile drapes arranged to leave the

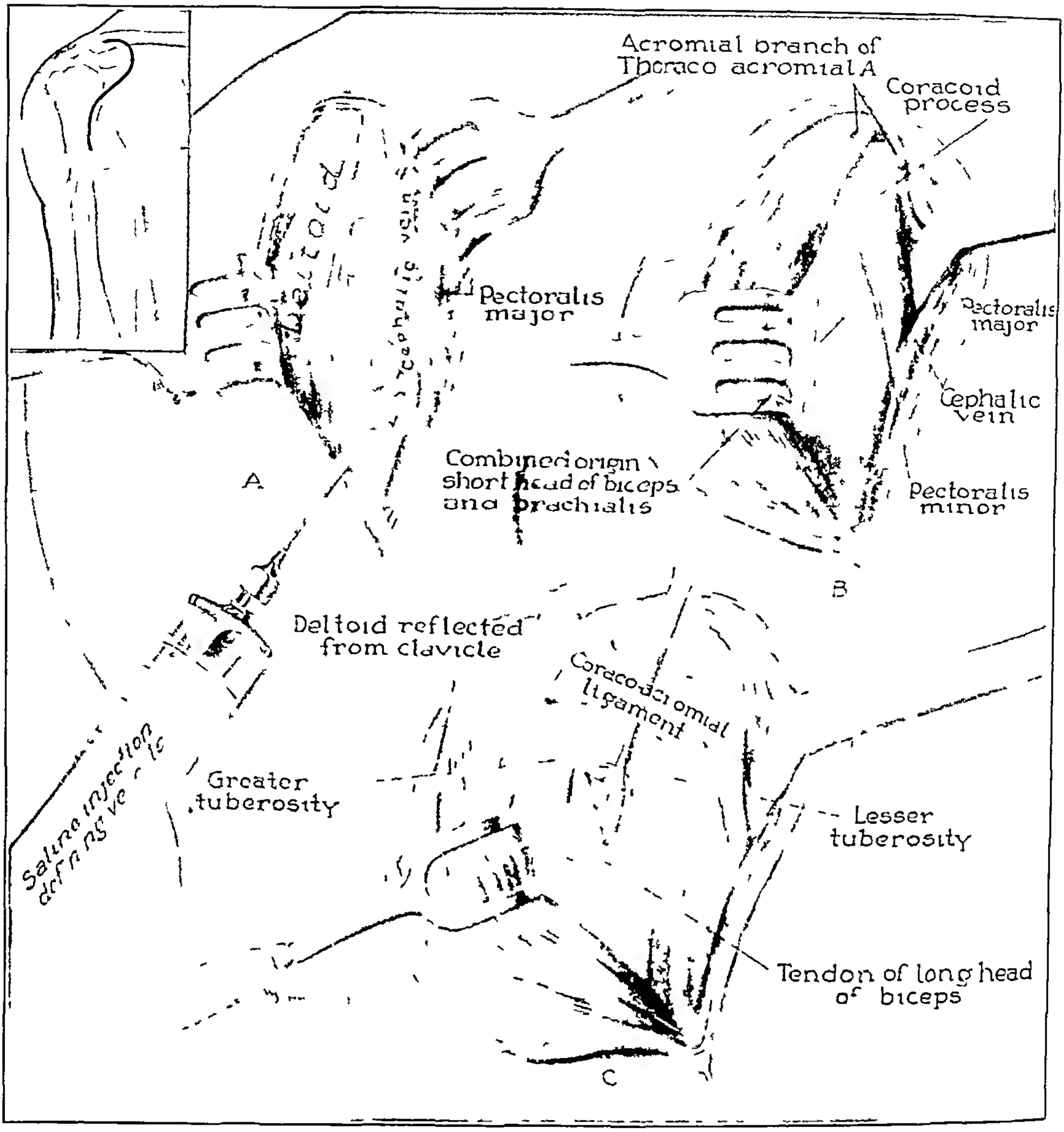

FIG 4

Approach to the anterior aspect of the shoulder with curved incision to prevent excessive scar (method of Hitchcock)
A Saline injection to define cephalic vein (method of Bechtol)
B and *C* Exposure of deep structures

arm entirely free, in order to permit motion of the scapulohumeral joint A tilting operating table which holds the hips and knees in moderate flexion gives the desired slope upward behind the knees, so that the thighs rest against an inclined plane In this way the patient does not slide downward and out of position The tilting operating table also permits a quick change in the position of the patient in case of emergency, such as difficulty with the anaesthetic Recently the authors have used a folding dental chair, which is preferable because it permits two assistants to work with the surgeon, one on each side

Local anaesthesia is particularly suitable for operations upon the shoulder, and the authors have used it extensively in the removal of deposits from the musculotendinous cuff and for repair of rupture of the supraspinatus tendon Active movement of the arm by the patient during the operation helps materially in exposure of this joint through limited incisions, and also aids in diagnosis and in the repair of damaged structures

In addition, the sitting position is readily adaptable to operations upon the shoulder requiring general anaesthesia Here it is of importance to support the trunk on the chair or the folding table by means of straps placed around the legs, thigh, pelvis, and chest

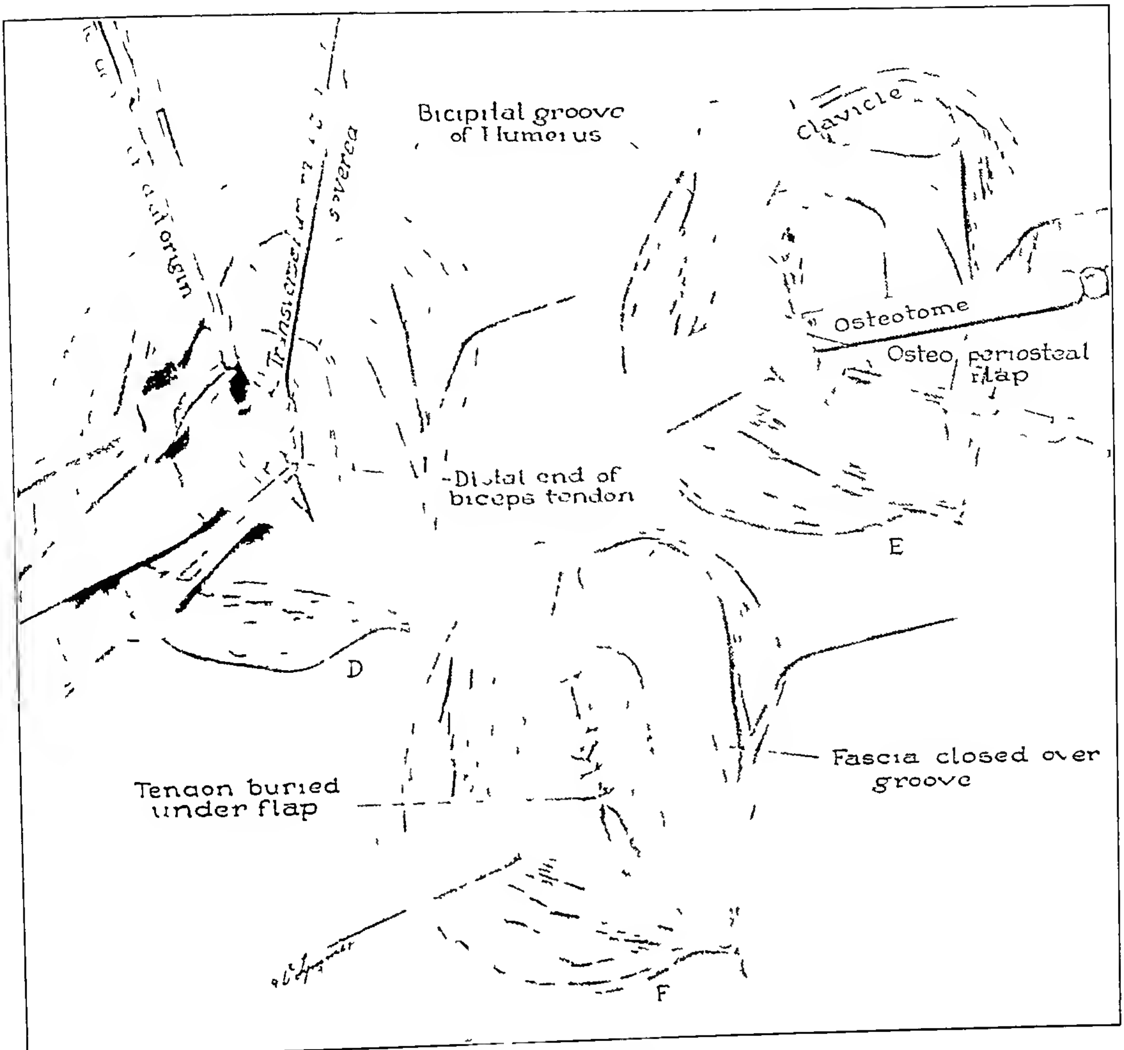

Fig 4 (*continued*)

D Excision of proximal portion of tendon of the long head of the biceps
E and *F* Fixation of distal portion of this tendon in the bicipital groove with osteoperiosteal flap, as described by Hitchcock and Bechtol Method of treatment in certain cases of tenosynovitis of the tendon of the biceps and associated subacromial bursitis

The head should be held on a special head rest in a posture which prevents strain on the neck In the authors' experience, intratracheal anaesthesia is preferable and eliminates completely the need for the anaesthetist to turn and twist the head in order to give the usual inhalation anaesthesia Failure to observe these principles of support for the trunk and head and to avoid torsion on the neck may produce serious injury with rotatory dislocation of the cervical spine Wilson observed a case of cervical dislocation that resulted from faulty use of the sitting position

Approaches to the Anterior Aspect of the Scapulohumeral Joint

1 *Deltopectoral Incision*

A *Indications* This incision is indicated for (1) fractures and dislocations of the shoulder, and (2) tenosynovitis and dislocation of the long head of the biceps

B *Position of the Patient* The patient is supine with the arm at the side, or supported in varying degrees of abduction by an arm board

C *Landmarks* The following landmarks should be observed (1) outer one-third of the clavicle, (2) acromion, (3) coracoid process, and (4) deltopectoral groove

D *Incision* An oblique incision is made in the skin along the anterior border of the deltoid, from the junction of the middle and outer thirds of the clavicle, downward almost

to the insertion of the deltoid muscle The margins of the deltopectoral groove are exposed and these two muscles are then separated, care being taken to protect the cephalic vein by preserving its fascial covering, together with a few fibers of the deltoid The vein is now retracted medially, and numerous tributaries of the cephalic vein and the deltoid division of the thoraco-acromial artery are ligated The deltoid muscle is retracted laterally to show the coracoid process, the deltoid portion of the subacromial bursa which overlies the lesser tuberosity, the anterior portion of the greater tuberosity, and the bicipital groove The bursa is opened to reveal the greater tuberosity of the humerus, the bicipital groove, the tendon of the long head of the biceps, and the anastomosing vessels which arise from the anterior circumflex artery and pass upward and downward in the groove By rotation of the humerus and separation of the long and short heads of the biceps, the lesser tuberosity and the medial lip of the bicipital groove, with the insertions of the tendons of the subscapularis, the teres major, and the latissimus dorsi, are exposed

This incision may be enlarged above by detachment of the deltoid from the outer third of the clavicle and the anterior margin of the acromion process, or below by partial subperiosteal separation of the tendinous insertions of the pectoralis major and deltoid into the shaft of the humerus (Figs 3 and 4)

2 *The Shoulder-Strap Incision of Henry*

A *Indications* are as follows (1) tumors of the anterior aspect of the joint, (2) fractures involving the joint, (3) arthrodesis of the joint, (4) recurrent dislocation of the shoulder, and (5) tenosynovitis or dislocation of the tendon of the long head of the biceps

B *Position of the Patient* The patient is either supine, with a small flat sandbag under the lower part of the scapula on the side of the operation, or, preferably, in the sitting position, with the shoulder well over the margin of the table and the arm draped to permit motion of the joint

C *Landmarks* The landmarks are the same as those for the deltopectoral incision

D *Incision* The anterior part of the skin incision is the same as for the deltopectoral incision At the upper end, this incision is extended from the tip of the coracoid over the superior aspect of the shoulder to the level of the spine of the scapula The cephalic vein is retracted medially with a few fibers of the deltoid muscle, and the deltopectoral groove is followed to the clavicle, thus exposing the anterior surface of the outer third of this bone and the adjacent margins of the acromion process With a thin-bladed osteotome the origin of the deltoid is detached, with a thin shaving of bone from the anterior margins of the clavicle and the anterior part of the lateral margin of the acromion Care should be taken not to cut too

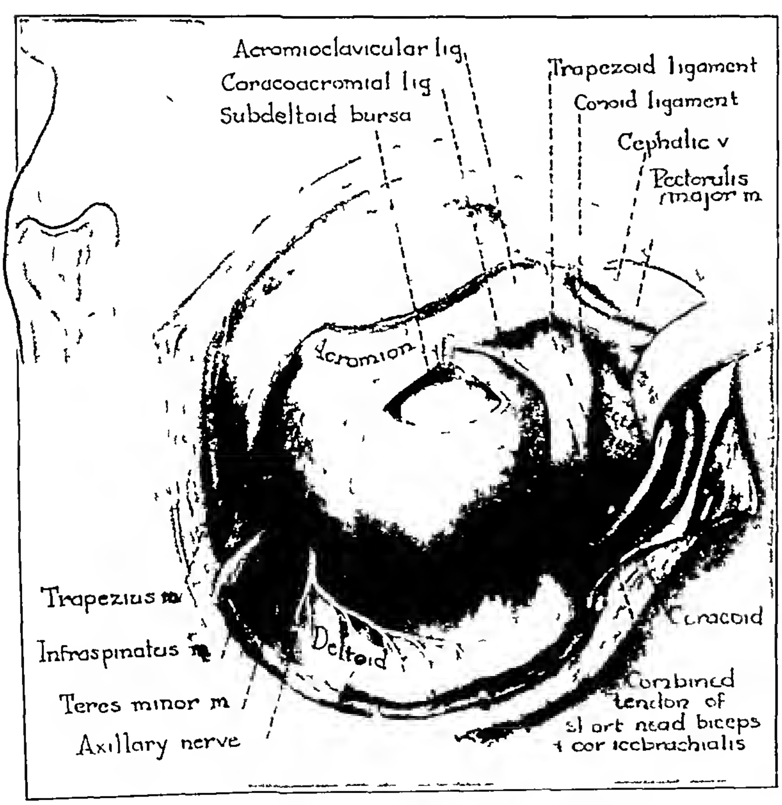

FIG 5

Exposure obtained by anterior and lateral segment of the "comprehensive" incision

deeply into the bone This approach exposes very adequately the coracoid process and its attached structures, the large subacromial bursa, the bicipital groove, and the tendons inserting into the greater tuberosity Upon incision into the bursa, these bony structures and their tendinous insertions are readily viewed Elevation of the origin of the deltoid may be continued around the lateral and posterior margins of the acromion and the adjacent spine of the scapula, to give complete exposure of the superior aspect of the shoulder joint

Recently the authors have exposed the deeper aspects of the scapulohumeral joint, including the anterior margin of the glenoid, through the anterior segment of the curvilinear or comprehensive incision, with detachment of the deltoid from the anterior margins of the clavicle and acromion (Fig 5) The coraco-acromial ligament is divided, one-half inch medial to its attachment to the acromion The periosteum over the coracoid is then incised proximal to the coracoid insertion of this ligament, and an osteotomy of this bone is performed With the coraco-acromial ligament being used as a handle, the distal segment of the coracoid is turned downward and inward with the origin of the coracobrachialis and short head of the biceps The upper and lower borders of the subscapularis are thus exposed and it is transected at the junction of its muscle and tendon, about one inch medial to its insertion into the lesser tuberosity of the humerus An incision is made through the anterior capsule, so that the anterior rim of the glenoid can be inspected

In recurrent dislocation, the tearing of the capsule from the labrum or the detachment of the labrum from the bone itself can be identified and repaired This repair is facilitated by a specially designed retractor, with which the head of the humerus can be displaced laterally and posteriorly, and by the use of instruments which permit drilling of the anterior margin of the glenoid At present the writers use the Putti-Platt method of repair, in which the anterior surface of the neck of the scapula is denuded and the distal segment of the subscapularis is sutured to the medial tip of the anterior capsule Further reinforcement is then secured anteriorly by suture of the muscle belly of the subscapularis to the scarified tendinous cuff which overlies the greater tuberosity or the bicipital groove This method was described in a recent article by Osmond-Clarke

Closure of the wound is accomplished by suturing or nailing the tip of the coracoid to the base of the coracoid process, or by subperiosteal excision of the tip and suture of the origin of the coracobrachialis and the short head of the biceps to the base of the coracoid The deltoid is turned back to its normal position and sutured to the clavicle and acromion Henry advocated resuture by a single loop suture around the clavicle For postoperative care, he suggested immobilization by sling or Velpeau bandage to maintain the arm at the side The period of immobilization depends upon the nature of the injury

3 *Longitudinal Separation of the Fibers of the Deltoid*

A *Indications* This method is recommended for (1) calcified deposits in the musculotendinous cuff, (2) rupture of the supraspinatus, and (3) fracture of the tuberosities of the humerus

Note The site of incision for removal of a calcified deposit depends upon its precise location within the musculotendinous cuff To determine the exact position of this deposit, the authors use roentgenograms and palpation for point tenderness Roentgenograms are taken of the scapulohumeral joint in the positions of external and internal rotation A vertical view to show the bicipital groove is also taken In external rotation a calcified deposit in the tendon of the supraspinatus is clearly shown above the greater tuberosity of the humerus, while in internal rotation the outline of the deposit is obscured by the overlapping shadow of the greater tuberosity Exactly the reverse is true when the deposit lies posteriorly, within the tendon of the teres minor Here, in the position of external rotation, the shadow of the greater tuberosity is superimposed on the shadow of the deposit, in internal rotation the deposit is clear and well defined laterally, and just inf tl

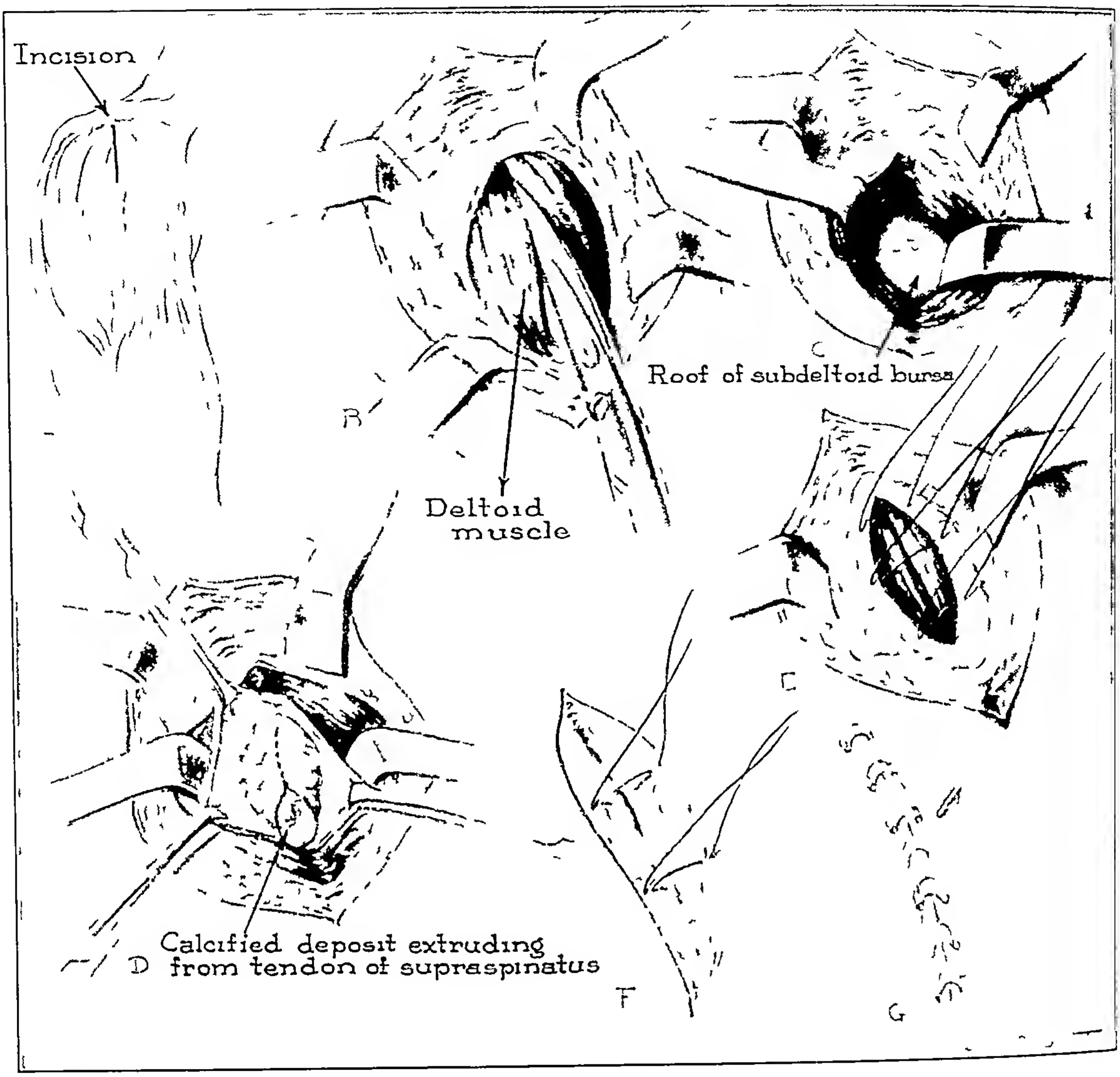

FIG 6

The muscle-splitting approach to the subacromial bursa and musculotendinous cuff (Reproduced, by permission of Appleton-Century-Crofts, Inc, from chapter by LeRoy C Abbott, M D, to appear in *Operative Technic*, edited by Warren H Cole, M D)

greater tuberosity Vertical views show the relation of these deposits to the margins of the bicipital groove and are, therefore, helpful in determining whether they lie in the subscapularis, supraspinatus, or infraspinatus tendons

While roentgenograms are an important aid in localization, in patients with acute symptoms, experience has taught us to rely upon point tenderness as the chief guide to the site of the incision

It is true that most deposits can be removed through an anterior incision and by rotation of the arm to bring all aspects of the insertion of the cuff beneath the incision However, if the deposit is in the tendon of the teres minor, in an acute case with marked spasm of the muscles or in a chronic case with adhesions, internal rotation of the arm may be so restricted that it prevents access to the deposit In such instances, where there is local tenderness on the lateral or posterolateral aspect of the shoulder, it is best to make an incision on the anterolateral or lateral surface In an occasional case where motion is limited by extreme spasm, the authors have found it necessary to relieve this condition by supplementing local anaesthesia with intravenous sodium pentothal

B *Position of the Patient* The patient is in a sitting position with the arm free at the side and the shoulder over the margin of the back rest The elbow is held at a right angle, with the forearm supinated

C *Landmarks* The landmarks are (1) acromioclavicular joint, (2) acromion, (3) humerus, and (4) bicipital groove

D *Anaesthesia* Local anaesthesia, consisting of 1 per cent novocain with adrenalin, is preferable except in cases where muscle spasm is marked and the patient is unable to relax In such cases the authors usually employ sodium pentothal intravenously

E A vertical incision of the skin is made along the upper segment of a line which is projected from the acromioclavicular joint to the middle of the anterior aspect of the elbow, with the arm at the side and the elbow flexed to a right angle (Fig 6) To avoid injury to the axillary nerve, the incision should extend downward for no more than one and one half inches from the anterior margin of the acromioclavicular joint The fascia covering the deltoid is split, and its fibers, which interlace in a bipenniform fashion, are separated and retracted with a self-retaining retractor In performing this step, the authors have found electrocautery useful for the coagulation of the small vessels as they cross the field of separation of the muscle fibers A dry field is thus maintained with minimum damage to tissues The roof of the subdeltoid bursa is seen, but not entirely divided until the deltoid fibers are separated throughout the length of the wound, particularly at the top of the incision over the margin of the acromion With the opening of the bursa and with voluntary movement of the arm, the insertion of the musculotendinous cuff into the tuberosities, the bicipital groove, and the anastomosing branches of the suprascapular and circumflex vessels are exposed The musculotendinous cuff can be seen as far back as the insertion of the teres minor, although this is sometimes difficult Therefore, as described in previous paragraphs, for complete rupture of the supraspinatus and for evacuation of calcified deposits in the posterior aspect of the cuff, a similar incision is used, but is placed farther laterally

Approaches to the Superolateral Aspect of the Shoulder Joint

1 *Longitudinal Splitting of the Deltoid Fibers*

2 *Longitudinal Splitting of the Deltoid Fibers with Partial Separation of the Deltoid from the Margin of the Acromion*

A *Indications* The indications are as follows (1) removal of calcified deposits which lie posteriorly, and (2) the repair of complete rupture of the supraspinatus

B and C The *position of the patient* and the *landmarks and incisions* are the same as for the anterior muscle-splitting incision, except that the incisions are placed over the superolateral aspect of the shoulder They begin on the superior surface of the acromion process and extend downward over its lateral border and the upper part of the deltoid The separation of the fibers of the muscle must not extend farther downward than from an inch to an inch and a half below the lateral border of the acromion, because of the danger of injury to the axillary nerve By subperiosteal removal of the deltoid origin from the acromion at the margins of the incision, the authors have repaired both partial and complete ruptures of the supraspinatus In the former, however, removal of irregular projection of scar tissue, bone, and the stub of tendon attached to the greater tuberosity will permit the smooth passage of this latter structure beneath the acromion and will relieve the symptoms

3 *Transverse Division of the Deltoid*

A *Indications* Arthrodesis of the shoulder joint

B *Position of the Patient* The patient may be in either the supine or the sitting position

C *Approach* The incision has two components The horizontal portion passes around the shoulder from front to back, one-half inch below the lateral margin of the acromion The vertical arm, beginning in the horizontal incision over the greater tuberosity of the humerus, extends downward two inches Two flaps of skin and subcutaneous tissue are

thus formed A deep incision is then made through the deltoid, at the tip of the lateral margin of the acromion The capsule is opened and freely excised to gain exposure of the joint The long head of the biceps, identified anteriorly, is separated from the groove The acromion process is denuded of all soft tissues on its inferior and superior surfaces, and fusion may then be accomplished by removal of the joint cartilage and mortising the acromion into the tuberosity of the humerus

4 *Separation of the Deltoid from Its Origin on the Clavicle and Acromion*

This approach, described by Cubbins, Callahan, and Scuderi and by Henry, is similar to Henry's shoulder-strap incision, already described A superolateral incision is begun anteriorly and curved around the margin of the acromion to the root of the spine of the scapula, and the deltoid is separated from its origin on the clavicle and acromion This approach gives an excellent view of the anterosuperior and superolateral aspects of the joint, and may be used for fractures, arthrodesis of the shoulder joint, and repair of the musculotendinous cuff

5 *Osteotomy of the Acromion Process*

A *Saber-Cut Incision of Codman*

1 *Indications* The indications are (1) repair of the musculotendinous cuff, (2) recurrent dislocation of the shoulder, (3) fixation of the tendon of the long head of the biceps in the bicipital groove, and (4) repair of fractures in the region of the greater and lesser tuberosities

2 *Position of the Patient* The patient is supine with the entire shoulder exposed laterally and posteriorly and the arm free, or, as in the authors' work, the patient is placed in the sitting position

3 *Approach* The incision begins anteriorly, one inch below the level of the acromion process, and passes directly upward over the acromioclavicular joint and then down the back of the shoulder to one inch below the spine of the scapula The fibers of the deltoid are separated anteriorly and posteriorly from above downward, and the ligaments of the acromioclavicular joint are severed The acromion process is divided by an osteotome, the division extending backward from the joint to a point medial to the angle of the acromion The divided acromion and attached deltoid are turned downward and retracted laterally to expose the subacromial bursa, the capsule of the shoulder joint, and the insertion of the muscles which form the musculotendinous cuff This retraction should be done with care, to avoid possible injury to the suprascapular nerve and transverse scapular artery, which pass through the suprascapular notch

The tendon of the long head of the biceps is exposed and, if the capsule is opened, the head of the humerus and the anteroposterior margin of the glenoid are brought into view

The objection to this approach, as described by Codman, is that there is a delay of postoperative movement The authors also have had two cases in which there was non-union of the acromion process, and second operations were necessary As in all deltoid-splitting incisions, care must be used to avoid injury to the axillary nerve

B *Transacromial Approach of Darrach and McLaughlin* The following approach, as described by Darrach and McLaughlin, is preferable to the Codman approach because the acromioclavicular joint is preserved The incision parallels the strap or suspender line in the normal skin creases of the region lateral to the acromioclavicular joint It extends from the posterior aspect of this joint to a point two inches in front of the anterior border of the acromion Anteriorly the bursa and the coraco-acromial ligament are exposed by separation of the fibers of the deltoid McLaughlin emphasized the importance of splitting

the fibers of the deltoid from above downward, beginning at the margin of the acromion, for in this way no unnecessary splitting is done and there is less danger of injury to the circumflex vessels and the axillary nerve

Exposure of the shoulder joint is then obtained by osteotomy of the acromion, in a line mid-way between the acromioclavicular joint and the lateral border of the acromion The deltoid is retracted laterally with the outer fragment of the bone For repair of the musculotendinous cuff, a more oblique osteotomy, deviating laterally to emerge at the lateral lip of the acromion, gives adequate exposure and a better cosmetic result The interior of the shoulder joint may be inspected by incisions through the musculotendinous cuff, between the margin of the glenoid and the anatomical neck of the humerus

McLaughlin prefers this approach to others for many reasons In fractures, bone fragments can be removed without being dragged through the brachial plexus Repair of the labrum glenoidale and the anterior capsule in recurrent dislocation is carried out from within the joint, avoiding the trauma of sectioning the coracoid and its attachments as well as of dividing the subscapularis tendon The removal of the fragment of the acromion also makes a less prominent fulcrum for impingement of the greater tuberosity in recurring dislocations of the shoulder The Nicola transplant of the biceps tendon, reduction and fixation of fractures, and other reconstructive procedures on the musculotendinous cuff can readily be performed through this exposure

Approaches to the Posterior Aspect of the Joint

1 *Approach of Kocher*

A *Indications* This approach is indicated for (1) posterior dislocation of the head of the humerus, (2) certain fractures of the head of the humerus and the posterior portion of the glenoid, (3) excision of the shoulder joint, and (4) tumors of the neck of the scapula

B *Position of the Patient* As recommended by Kocher, the patient is placed prone with his arm abducted on an arm board and pillows under the chest on the side of the operation, the head is turned to the opposite side An alternate position, which the authors prefer, is the sitting position with the shoulder well over the side of the table and the arm free

C *Landmarks* The landmarks are (1) acromioclavicular joint, (2) acromion process, (3) spine of the scapula, and (4) posterior border of the deltoid

D *Incision* The incision begins at the acromioclavicular joint and extends backward along the outer border of the acromion to the spine of the scapula It is then curved downward, ending two fingerbreadths above the posterior fold of the axilla The superior and posterior ligaments

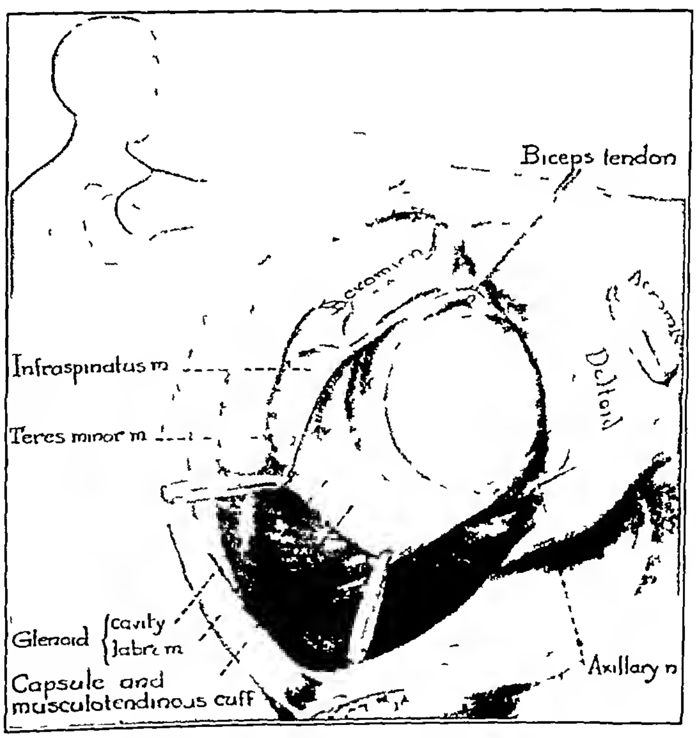

Fig 7

The posterior approach with subperiosteal detachment of the deltoid and osteotomy of the lateral margin of the acromion This is used especially for arthrodesis of the shoulder, with the patient in the sitting position

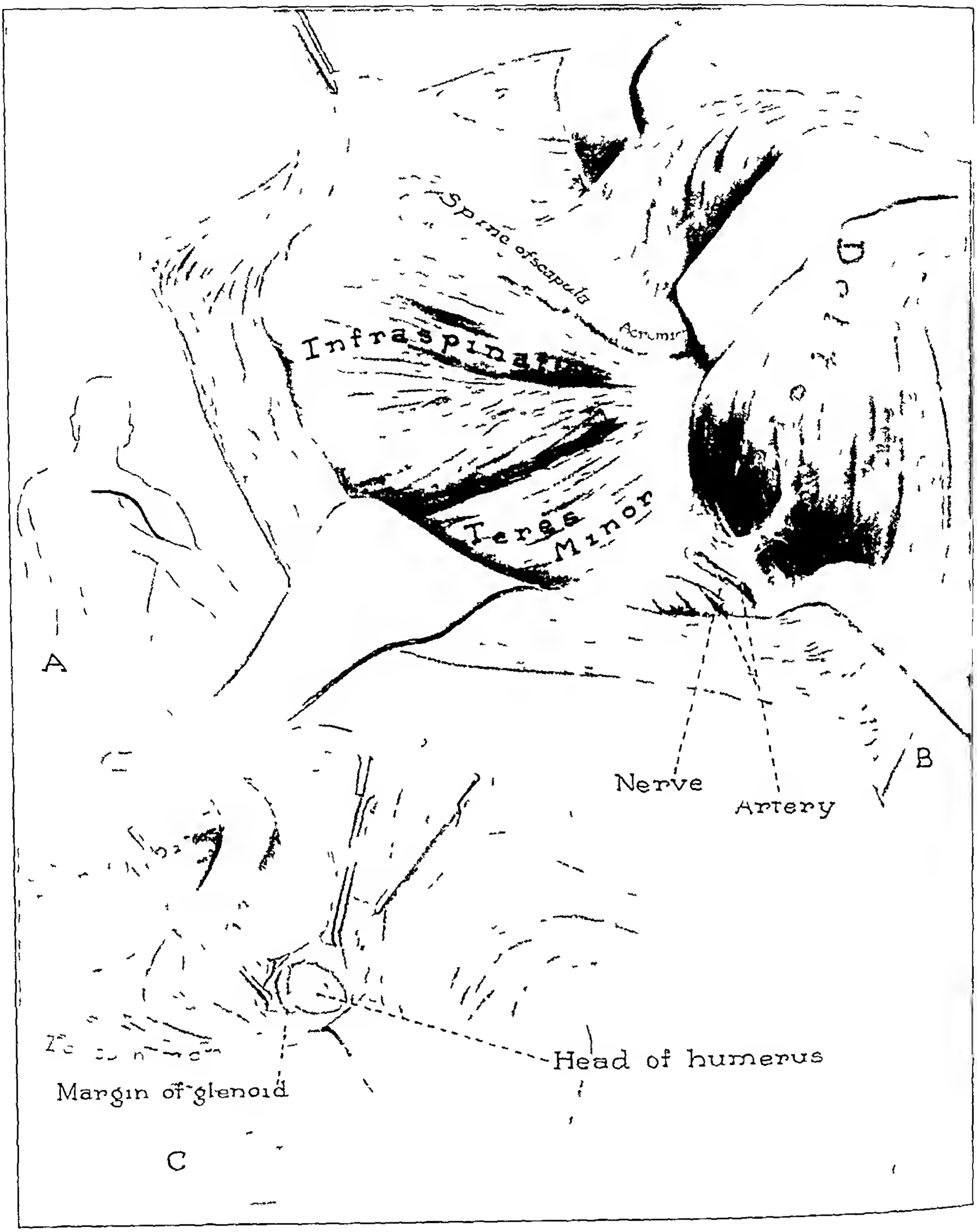

Fig. 8

A and *B*: Posterior approach for exposure of the posterior inferior portions of the scapulohumeral joint, between the infraspinatus and teres minor (method of Bennett).
C: Capsule incised in line of fibers, exposing head of humerus and margin of glenoid.

of the acromioclavicular joint are divided, and the trapezius is separated from the spine of the scapula. Through the descending limb of the incision, the dense fascia over the posterior border of the deltoid is divided.

The deltoid origin is then freed from the scapular spine as far laterally as the posterior margin of the acromion, a margin of tissue being left on the bone for resuturing. By detaching the upper border of the infraspinatus, an interval is developed so that the finger can be passed around the root of the acromion. Here the suprascapular nerve and the transverse scapular artery must be carefully isolated and protected. The acromion is then oste-

otomized obliquely and the outer segment is retracted with the deltoid As an alternative to division of the bone, the deltoid is separated from the spine of the scapula and the acromion, as far forward as the acromioclavicular joint Lifting this deltoid curtain readily reveals the head of the humerus and the muscles inserting into the greater tuberosity The capsule is then divided over the very top of the humeral head The tendon of the long head of the biceps is freed from its groove and retracted forward

The external rotators are divided, enough tendon being left attached to the bone for suturing, and the muscles are drawn backward The anterior portion of the capsule should be left intact, even though in some cases it may be necessary to detach the insertion of the subscapularis The integrity of the anterior portion of the capsule limits the tendency of the head of the humerus to become displaced upward and inward toward the coracoid process By this method a wide exposure of the head of the humerus is obtained without impairment of function of the deltoid

The writers have used a modification of the Kocher approach for arthrodesis of the scapulohumeral joint, with the patient in the sitting position (Fig 7) For this operation the dental chair is particularly suitable, as the entire posterior and superior aspects of the shoulder with its bony landmarks are accessible to the surgeon Beginning at the anterior border of the acromion, the incision is curved over its lateral margin and then along the inferior edge of the spine of the scapula to the junction of its inner and middle thirds From here it turns outward and downward in a gentle curve, to follow the posterior margin of the deltoid for a short distance, and it terminates near the inferior angle of the scapula In the lower part of the wound the margin of the deltoid is identified and followed to its origin from the spine of the scapula The periosteum is divided over the center of the spine of the scapula and acromion process, and reflected laterally with the origin of the deltoid as far as the edge of the acromion This edge is divided with an osteotome, thus completely freeing the origin of the posterior segment of the deltoid with the exception of the innermost part of its origin, which is often transected This muscle is then turned outward to expose the greater tuberosity of the humerus and the musculotendinous cuff The teres minor tendon should be identified here, as it forms the upper boundary of the quadrilateral space which contains the axillary nerve and the posterior circumflex vessels

The tendinous insertion of the cuff is divided, a stub being left attached to the greater tuberosity to facilitate repair The cuff is turned medially to expose the capsule of the joint With division of this structure, the posterior aspect of the joint is readily viewed The cartilage is removed from the glenoid and the head of the humerus with special gouges The inferior and superior surfaces of the acromion are scarified, and its junction with the root of the spine of the scapula is partially divided with an osteotome A vertical groove is cut in the humerus, directly medial to the greater tuberosity With the arm abducted to approximate the denuded glenoid and head of the humerus, the osteotomy of the acromion is completed by bending it and fitting it into the groove in the humerus Fixation of the joint is secured by screws, which are turned *through the outer cortex of the upper portion* of the shaft and the head of the humerus, and into the glenoid The insertion of the musculotendinous cuff is pulled up and over the acromion and stitched to the periosteal insertion of the trapezius The inferior margin is then stitched to the stub of the cuff on the greater tuberosity This binds the acromion into the groove of the humerus and gives additional fixation The origin of the deltoid is repaired with interrupted sutures, and the skin is closed in the usual manner

2 *Posterior Approach of Harmon*

A *Incision* The incision is begun in the middle of the spine of the scapula and is carried outward to the angle of the acromion The origin of the deltoid on the spine of the scapula and the acromion is detached and reflected laterally and inferiorly In this step the deltoid should not be retracted below the level of the belly of the teres minor lest the axil-

lary nerve be injured With the arm in a neutral position as regards rotation, a vertical incision is made through the tendinous portion of the rotator cuff, just above the belly of the teres minor and the quadrilateral space Harmon stated that this gives extensive exposure to the humerus, being inferior only to the saber-cut method in the extent of the exposure

3 *Approach of Rowe and Yee*

A *Incision* The incision is begun at the junction of the middle and inner thirds of the spine of the scapula and is extended laterally to the outer segment of the spine It is then curved downward over the posterior aspect of the shoulder joint for about four inches Retraction of the skin exposes the deltoid origin from the spine of the scapula Approximately one and one-half inches from the medial border of the deltoid, this muscle is split in a downward direction for a distance of three inches The portion of the muscle lateral to the vertical incision through its substance is formed into a triangular flap by subperiosteal reflection of its origin from the spine of the scapula This exposes the infraspinatus and teres minor The approach to the joint is secured by separating these two muscles and freeing the infraspinatus from the underlying capsule The tendon of attachment of the infraspinatus is divided half an inch from its insertion into the greater tuberosity, and is retracted medially Retraction of the teres minor inferiorly exposes the capsule of the posterior and inferior aspects of the shoulder joint Rowe and Yee emphasized the importance of keeping the incision above the teres minor, in order to avoid injury to the axillary nerve which passes here through the quadrilateral space The interior of the posterior and inferior aspects of the shoulder joint can be exposed adequately by a vertical incision through the capsule

4 *Approach of Bennett*

In 1941, Bennett described an approach to the posterior aspect of the shoulder for removal of deposits of bone on the posterior-inferior border of the glenoid fossa He showed that these deposits occur in baseball pitchers, as a result of excessive use of the arm and a tremendous pull on the posterior portion of the capsule and the tendon of the long head of the triceps

A curved incision is made over the posterior aspect of the shoulder, and the origin of the deltoid is detached from the spine of the scapula and retracted laterally The posterior capsule of the joint is exposed in the interval between the tendons of the infraspinatus and teres minor The infraspinatus is supplied by the suprascapular nerve, entering its substance from above, while the teres minor is supplied by the axillary nerve which enters it from below Therefore, there is little danger of injury to either nerve by separation of the adjacent borders of these two muscles The authors have found this approach satisfactory for exposure of the postero-inferior aspect of the scapulohumeral joint (Fig 8)

Approaches to the Inferior Aspect of the Joint

Approaches to the inferior aspect of the shoulder joint may be achieved by the method of Thomas, which reaches the capsule at the inferior aspect of the joint by an incision along the margin of the posterior fold of the axilla To our knowledge, this approach is not in use at the present time Other approaches to the axilla, usually for purposes of drainage of the axillary space, are made along the inferior margin of the pectoralis major Incisions of this type may occasionally be needed for drainage of pus which has migrated from the shoulder joint to the axilla, or, more commonly, for accumulations of pus arising from infected axillary glands

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SURGICAL TREATMENT OF NON-UNION OF LONG BONES *

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This paper is based on three years' experience in the National Center of Reconstructive Surgery We are presenting 126 cases of non-union of long bones, treated by different methods, together with their end results Most of these cases were war wounds, many with large bone defects and severe infection

Among the first 102 cases (Table I), sixty-four were war wounds, of which forty-two showed large bone defects All of the forty-two and many of the others were or had been severely infected A certain number of these men had been wounded during the "underground" fighting, when no penicillin was available and the facilities for surgical treatment of compound fractures were extremely bad

TABLE I

NON-UNION OF THE LONG BONES

Location	Open Fractures		Closed Fractures (Early Treatment)		Total
	Without Loss of Bone Substance	With Loss of Bone Substance	Open Reduction	Non-Operative	
Femur	3	6	5	4	18
Tibia	9	10	6	4	29
Humerus	6	15	4	3	28
Both bones of forearm	3	4	5	4	16
Radius or ulna alone	1	7	2	1	11
Totals	22	42	22	16	102

TABLE II

RESULTS IN 126 CASES

Location	No of Cases	Consolidations (Union)					Failures
		No of Interventions			Total		
		1	2	3	Number	Per cent	
Humerus	32	25	3	1	29	90	3
Both bones of forearm	18	17		1	18	100	0
One bone of forearm	16	15		1	16	100	0
Femur	19	14	3	1	18	95	1
Tibia	41	32	4	2	38	93	3
Totals	126	103	10	6	119	94	7

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 28, 1948

** Created by the Ministry of War in 1944 Organized and directed by the author

TABLE III

NON-UNION OF THE HUMERUS

Operative Method	No. of Operations	Consolidations		Failures	Average Period before Union Was Obtained (*Months*)
		No.	Per cent		
Metallic fixation					
Encircling wire	2	2	100	0	4
Screws	4	4	100	0	2½
Kuntscher nail	4	2	50	2 (1 reoperation)	3
Tibial graft					
Intramedullary	2	0		2 (1 reoperation)	
Fixed by encircling wire	4	2	50	2 (1 reoperation)	3
Fixed by screws	12	11	92	1 (1 reoperation)	3½
Kuntscher nail plus graft	8	8	100	0	6
Totals					
Operations	36	29	80	7	
Cases	32	29	90	3	

Thirty-eight of these were simple fractures; sixteen of the patients had not been operated upon previously. Twenty-two had been treated by open reduction and bone-plating, often because of the impossibility of following the cases. These figures suggest that an important cause of non-union in fractures of the long bones, whether in war fractures or in the compound fractures of civil practice, is bone-plating done with improper technique.

We consider the guiding principles for the treatment of these cases to be as follows:

Before Operation

1. To eliminate the infection as completely as possible;
2. To provide, as accurately as possible, sound soft parts around the site of fracture.

At Operation

3. To maintain the best possible blood supply to the fragments;
4. To secure sound internal fixation of the fragments;
5. To obtain firm bone contact, with pressure of each fragment against the other, or, if this is impossible because a bone defect is present, firm contact of a bone graft on both fragments;
6. In all cases to bring to the site a new bone-forming tissue to secure more rapid callus formation.

After Operation

7. To obtain good circulation and nutrition of the limb by immobilization in the most favorable position and by early active exercises of the muscles, even within the plaster cast.

In our experience, when all these principles have been observed, good bony union has always occurred. All the failures have been due to the non-observance of one or more of these rules.

The aim of this paper is not to emphasize the preoperative measures, or the need for re-education. We will only note that in every case of infection, in a preliminary operation, the fibrous tissue and the infected bone were thoroughly resected and, after a saucerization, the defect was filled by sound soft tissue,—namely, a pedicled muscle flap on deep bones (such as the humerus or femur) and a pedicled skin flap on superficial bones (fore-

TABLE IV

Non-Union of the Forearm

Operative Method	No. of Operations	Consolidations		Failures	Average Period before Union Was Obtained (*Months*)
		No.	Per cent		
Metallic fixation					
Plate	9	6	67	3	5
Nail	9	7	78	2	4
Tibial graft with screws	35	32	91	3	4½
Nail and graft	4	4	100	0	4
Totals					
Operations	57	49	86	8	
Cases					
Two bones	18	17	94	1*	
One bone	16	16	100	0	
Total cases	34	33	97	1	

* Union of one bone, non-union of the other.

TABLE V

Non-Union of the Femur without Lengthening (with or without Moderate Bone Defect)

Operative Method	No. of Operations	Consolidations			Failures	Average Period before Union Was Obtained (*Months*)
		Normal	Delayed or with Complications	Per cent		
Metallic fixation						
Encircling wire	1	1				5
Kuntscher nail	10	7	2	90	1*	5
Graft						
Iliac	1 (after nailing)	1				3
Tibial	1	1				5
Sliding	1	1				3
Kuntscher nail plus tibial graft	3	3		100		3
Totals						
Operations	17	14	2	94	1	
Cases	16	13	2	94	1	

* Callus, but pain on walking; x-ray result mediocre.

arm or tibia) A delay of two months for the upper extremity and of four months for the lower extremity was always observed after complete healing before the bone operation was performed

The incidence of recurrent infection is quite different for the upper and lower ex-

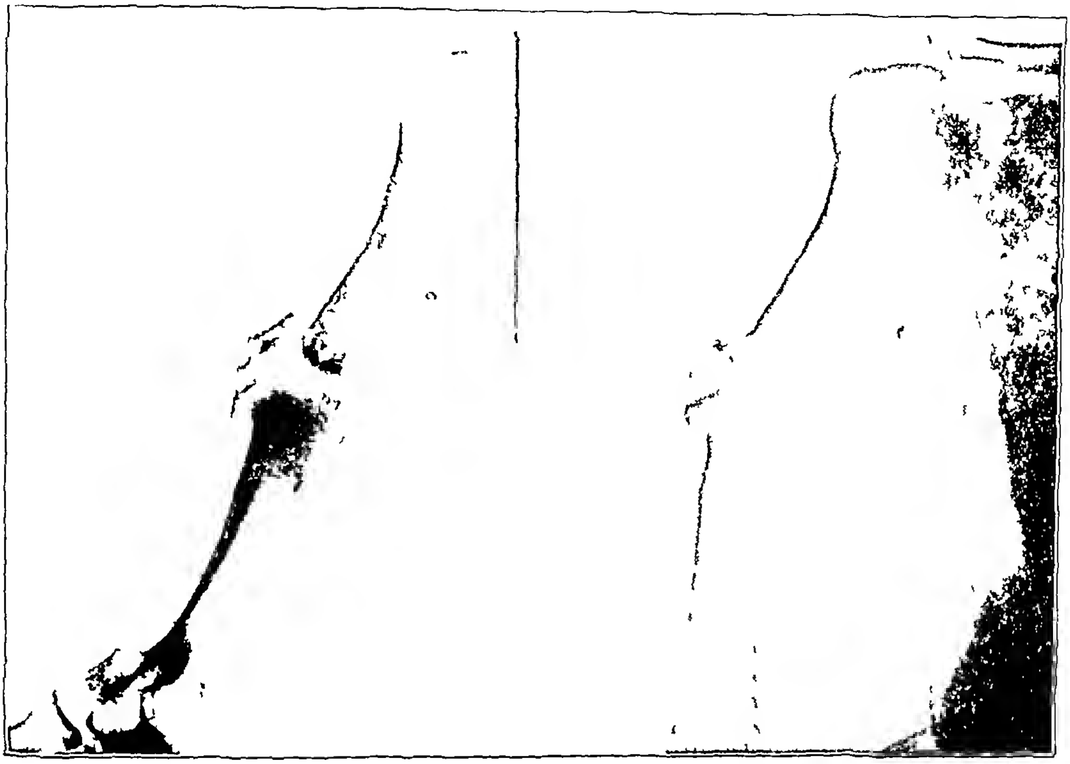

Fig 1-A

April 21, 1947 Non-union of humerus of three years' duration

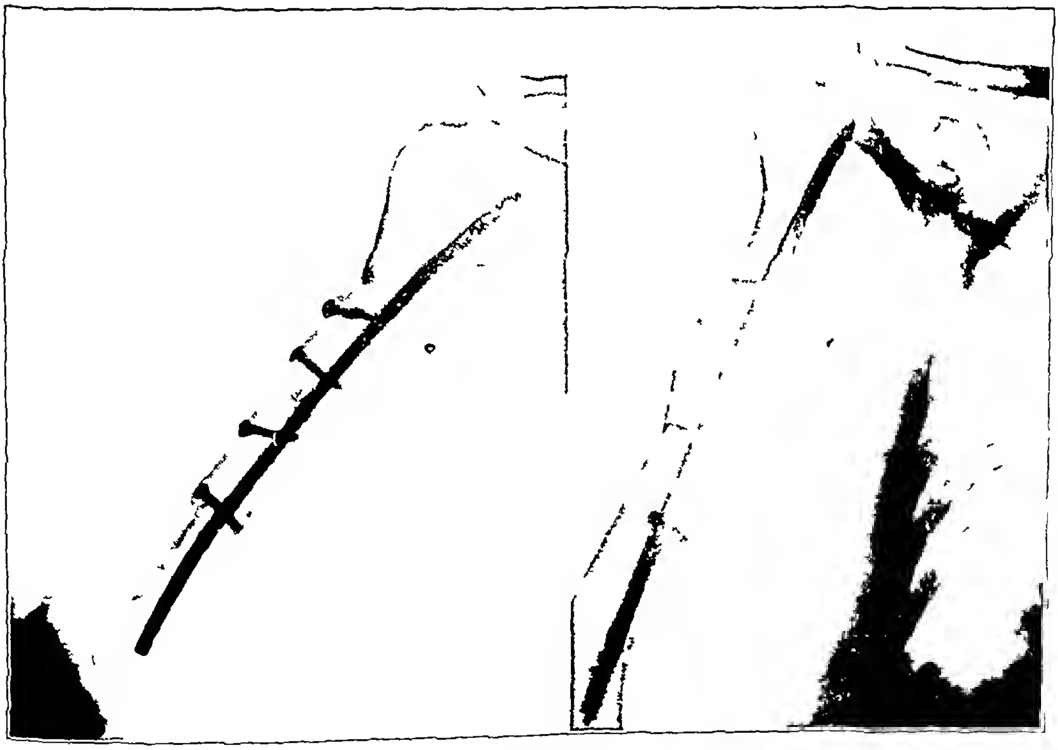

Fig 1-B

October 6, 1947 Six months after treatment with intramedullary nail and tibial graft

Fig 2-A

January 6, 1947 Non-union of forearm with infection

Fig 2-B

June 4, 1947 Union five months after tibial graft

tremities (Table II) In sixty-six cases of non-union of the humerus or forearm, there was only one infectious flare-up resulting in failure In sixty cases of non-union of the femur or tibia, serious flare-ups occurred in eight cases, resulting in complete failure in three, and in long-persisting sinuses in five cases

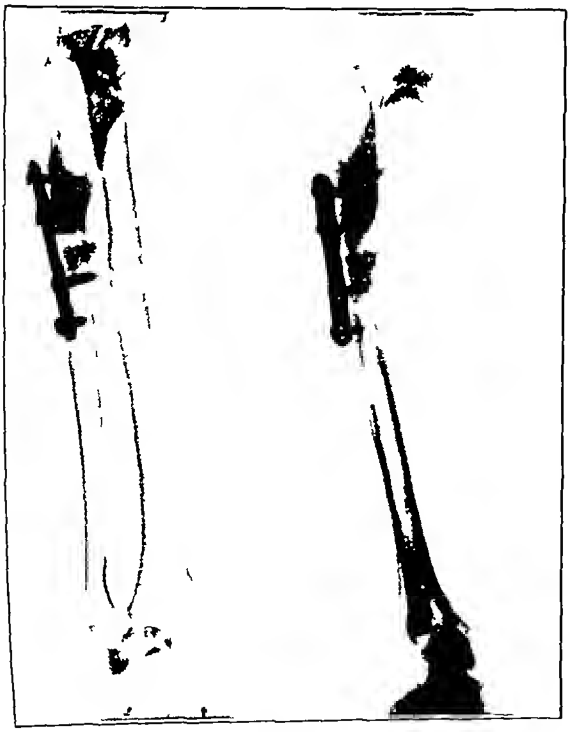

Fig 3-A

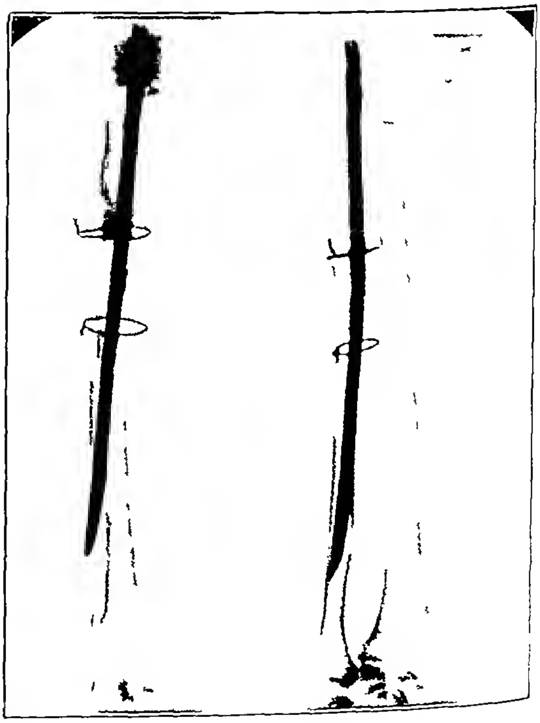

Fig 3-B

Fig 3-A May 30, 1947 Monteggia fracture with non-union of ulna
Fig 3-B October 11, 1947 Union four and one-half months after nailing and grafting (An iliac graft was used)

This difference is due, in our opinion, to the very deep infection of the muscles in war wounds of the thigh and, in non-union of the tibia, to the reopening of the suture line by infectious necrosis of the flap

Three types of bone operations have been used in most of these cases

1 Metallic fixation, particularly by intramedullary nailing (Kuntscher method),

2 Bone graft,—a tibial graft with screws in a large number of cases, with bone chips in some cases,

3 Bone graft combined with intramedullary nailing This method is believed to be the best in many cases

Other methods were used, but only in a small number of cases A comparative study of the results with the three methods just mentioned has been done for the different long bones

UPPER EXTREMITY

Non-Union of the Humerus

In twelve of thirty-two cases, the tibial onlay graft was used, fixed by screws, with only one failure due to recurrent infection (Table III) This is an excellent method When a bone defect is present, either the bone ends can be brought together or the defect can be bridged by the graft This bridging procedure was so consistently successful that we think it is advisable to maintain the normal length of the limb in all cases except those in which, because of an associated nerve defect, the shortening of the bone permits an end-to-end nerve suture This suture has always been performed in the same stage

To prevent possible fracture of the graft, the arm has to be kept in an abduction plaster cast for at least sixteen weeks This, of course, is a serious drawback This long period of immobilization can be avoided by the use of the Kuntscher nail Of four cases in which the nail was used alone, two were successes and two were failures In one case the fragments pulled apart, in the other, where a bone suture had been done in addition, the nail broke after five months

On the contrary, results are very good if the nail is reinforced by a small tibial graft which, in addition to providing fixation, supplies osteogenetic material The nail is introduced from the olecranon fossa and directed upward The graft is fixed by screws,

TABLE VI

NON-UNION OF THE TIBIA WITHOUT BONE DEFECT

Operative Method	No of Operations	Consolidations			Failures	Average Period before Union Was Obtained (*Months*)
		Normal	Delayed or with Complications	Per cent		
Metallic fixation						
Plate	4	4		100		5
Nail	2	1		50	1	
Bolt or screws	2	2		100		3
Graft						
Sliding	12	7	3	83	2	6
From opposite side	6	6		100		4
Iliac	3	3		100		6
Kuntscher nail and graft	1	1		100		5
Totals						
Operations	30	24	3	90	3	
Cases	28	25	2	96	1	

driven alternately on each side of the nail The arm may be removed from the cast at the end of the first month and active exercise resumed This method was successful in the eight cases in which it was used

Non-Union of the Forearm

In the forearm, the author believes that the tibial graft fixed by screws is the best method The nail is useful only when a tibial graft cannot be employed, in multiple fractures, or in fracture of the ulna at a high level, where accurate fixation of a graft would be difficult

In this series union was obtained in all cases, with the exception that, in one case of non-union of both bones of the forearm, one bone remained ununited after operation Of these thirty-four cases, eighteen had large bone defects (Table IV) A proper technique always gives good results in non-union of the upper extremity, even when large bone defects are present

LOWER EXTREMITY

In the lower extremity, the difficulties and dangers encountered in non-union of the femur or tibia depend largely upon the presence and the importance of the bone defect Consideration will be given, first, to those cases in which the bone defect is either absent or moderate enough to allow the surgeon to put the fragments together without too great shortening of the limb, and, second, to those cases in which an important bone defect must be bridged

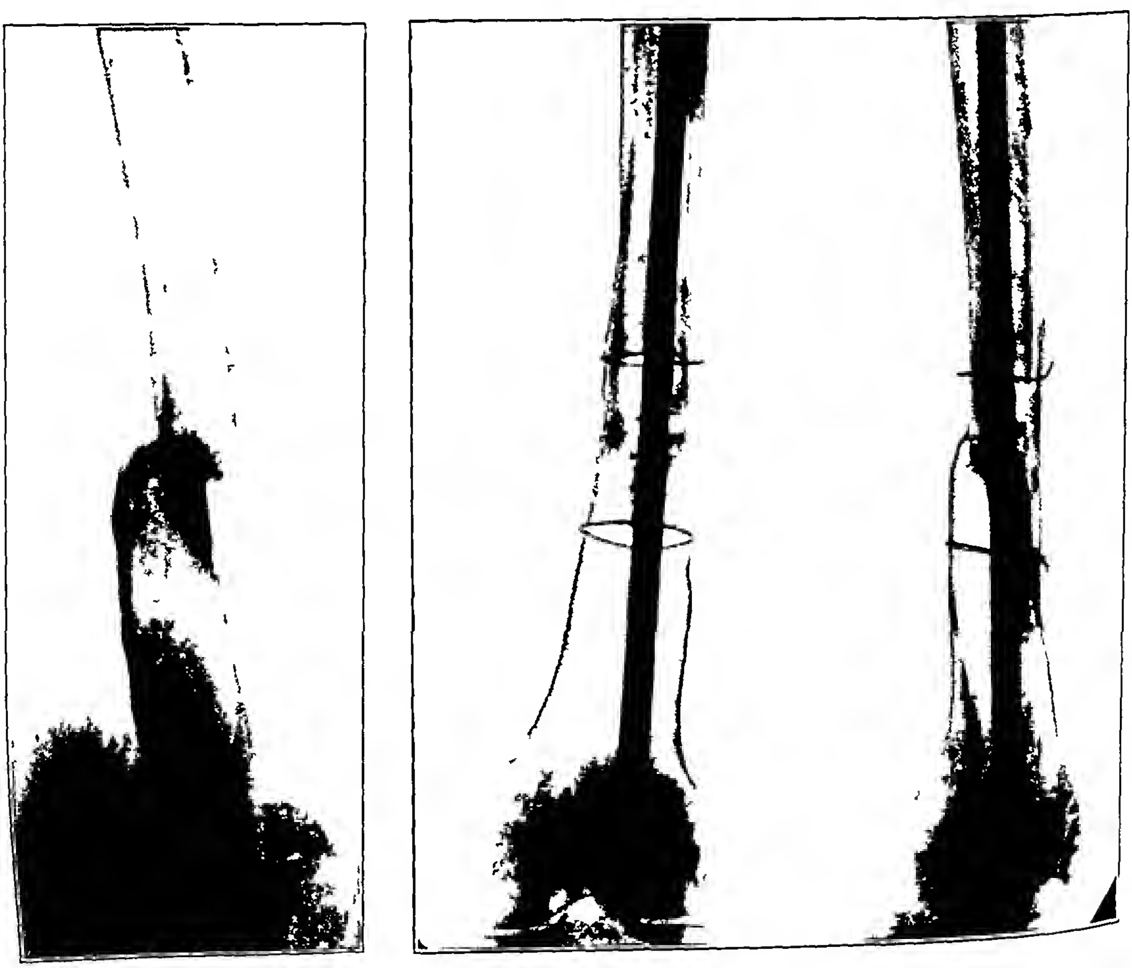

FIG 4-A FIG 4-B

Fig 4-A April 12, 1946 Non-union of femoral shaft of one year's duration
Fig 4-B May 7, 1947 Union five months after nailing and application of a sliding graft

Non-Union without Important Bone Defect

1 *Femur* When the bone defect is less than four centimeters, it is better to bring the fragments together When overriding of the fragments exists, one must not resect the bone ends more than the minimum necessary to perform an end-to-end reduction, this is important, not only to avoid unnecessary shortening of the limb, but also to secure strong pressure of the bone ends on one another

In these cases, intramedullary nailing is the method of choice In this series, it was applied in thirteen cases with almost uniform success (Table V)

After the bone ends have been exposed and freshened, a proper nail is introduced from below upward into the superior fragment, and brought out of the thigh by a small incision over the trochanter Then the fragments are reduced and the nail is driven into the inferior fragment

In the first cases treated, the soft parts were closed afterward, a plaster cast was applied and left on for one month, and the patient was allowed to walk with canes In three instances, however, consolidation was delayed, and after five or six months the nail bent (one case) or broke (two cases) Therefore, we think it necessary in all cases to complement the nailing by a graft fixed with screws In seven cases so treated, consolidation always occurred normally in two or three months, the patient being allowed to walk from the end of the first month

2 *Tibia* Except for a few oblique fractures, successfully treated by freshening the fragments and fixing with screws, all cases of non-union in the tibia were treated by grafting

The inlay graft is preferred, for it provides good fixation, often without any metallic material The graft may be taken from the same tibia (sliding graft) or from the opposite

Fig 5-A

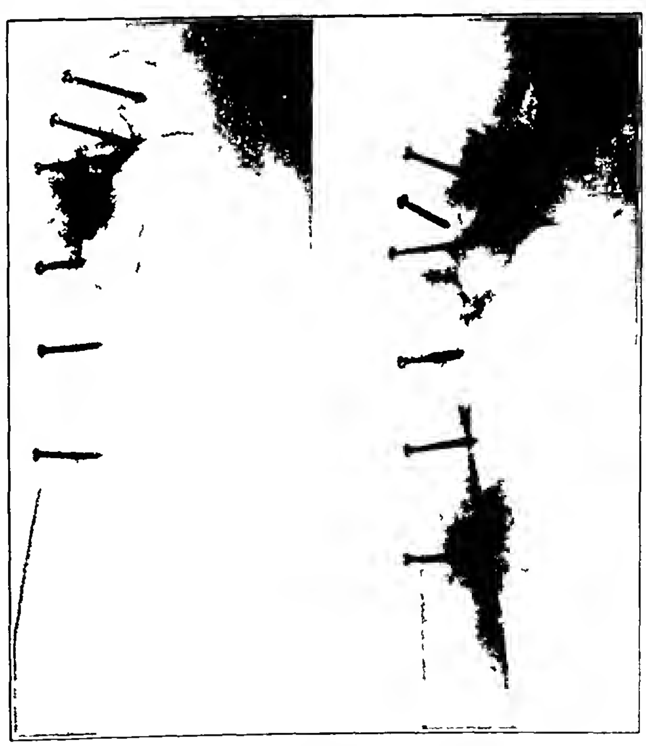

Fig 5-B

Fig 5-A Case 110 December 10, 1945 Large bone defect of femur after war wound (11 centimeters of shortening)

Fig 5-B October 6, 1947 Union eight months after grafting with tibial and iliac grafts The shortening has been reduced to 5 centimeters

FIG. 6-A

FIG. 6-B

Fig. 6-A: September 17, 1946. Bone defect of tibia after war wound.
Fig. 6-B: May 31, 1947. Seven months after inlay tibial graft and cancellous bone grafts, union has occurred.

one. Notwithstanding its advantages, the sliding graft is not so safe as a graft from the opposite side. In three of twelve cases, a fracture of the graft occurred (Table VI), in one case while the plaster was being applied, immediately after the operation, in the other two, at the third or fourth month. On the other hand, six grafts from the opposite side resulted in six successes.

Large Bone Defects of the Lower Extremity

The treatment of such cases is much more hazardous, the greatest risk being the recurrent infection, always to be feared in these fractures with severe infection.

When the bone defect is very large, it is difficult to provide good fixation of the fragments. Therefore, a Kuntscher nail was used, the defect around the nail being filled with iliac chips. This technique was used in five cases,—two femora with large bone defects

TABLE VII

NON-UNION OF THE FEMUR WITH LENGTHENING

Method Employed	Operative Results	Clinical Results
Kuntscher nail plus iliac graft Case 28 (defect of 12 cm.) Case 31 (defect of 10 cm.)	Severe flare-up of infection. Deep, prolonged drainage until removal of nail and some of the graft	 Union in 22 months Union in 14 months
Tibial and iliac grafts Case 110 (defect of 11 cm.)	Uncomplicated. No flare-up of infection	Union in 5 months. In sixth month graft fractured under plaster spica. New graft united

TABLE VIII

NON-UNION OF THE TIBIA WITH LARGE BONE DEFECT * (THIRTEEN CASES)

Operative Method	No of Operations	Consolidations			Failures	Average Period before Union Was Obtained
		Normal	Delayed or with Complications	Per cent		
Iliac graft						
Alone	1				1	Reoperation
Plus Kuntscher nail	3	0	1**	33	2	1 amputation, 1 reoperation
Tibial graft						
Inlay	1		1**			
Sliding	1	1				8 months
Tibial graft plus iliac chips	8	7		88	1	6 months (1 in treatment)
Totals						
Operations	14	8	2	64	4	
Cases	12†	8	2	83	2	

* Defects varied from 3 to 12 centimeters, averaging 8 centimeters

** Iliac graft added

† One patient still under treatment

(10 centimeters and 12 centimeters) and three tibiae The results were not satisfactory (Table VII) One of the femora is now strong and free from infection, in the other a little sinus is still present, but there is fair callus, one of the tibiae has united All five cases, however, showed very serious recurrent infection, all or part of their grafts were eliminated, and suppuration ceased only after removal of the nail In two of the tibiae the result was a complete failure

Therefore, we have now given up this technique and we always use a very long, wide tibial graft This graft is inlaid in the fragments, the pieces of bone removed from the fragments are laid in the bone defect, and iliac chips are inserted in every free space This method was successful in eight cases out of nine,—namely, in one femur and in seven of eight tibiae (Table VIII)

CONCLUSIONS

1 The *intramedullary nail* provides an excellent method of fixation for certain cases of non-union of the long bones Its advantages for the femur and humerus are particularly striking, it reduces the time of immobilization in a cast to one month, and affords early rehabilitation of the muscles and joints This is very important, as these patients have already been confined to bed for many months However, the Kuntscher nail must be discarded in all cases with previous deep infection, because of the risk of recurrent infection, as well as in those cases in which a large bone defect is present, especially at the femur or tibia In addition, it must always be combined with a bone graft, firmly fixed to the fragments by screws

2 The *tibial graft* alone is the best method for the tibia (inlay graft) and for the forearm (onlay graft) It must be fixed very firmly If the onlay method is employed, screws are the best means of fixation (Tables IX and X)

3 The *cancellous bone* taken from the iliac crest is the best material to fill bone defects

TABLE IX

NON-UNION WITHOUT BONE DEFECT

Method Employed	Humerus		Radius and Ulna		Femur		Tibia		Total	
	No	Per cent of Union	No	Per cent of Union	No	Per cent of Union	No	Per cent of Union	No	Per cent of Union
Nail alone	4	50	9	78	10	70	2	50	25	68
Graft alone	18	72	35	91	3	100	21	80	77	84
Nail and graft	8	100	4	100	3	100	1	100	16	100
Totals	30		48		16		24		118	

TABLE X

BONE DEFECTS

Method Employed	Humerus		Forearm		Femur		Tibia		Total	
	No	Per cent of Union	No	Per cent of Union	No	Per cent of Union	No	Per cent of Union	No	Per cent of Union
Nail plus cancellous bone	2	100			2	50	3	0	7	75
Tibial graft plus cancellous bone	3	100	11	100	2	100	8	88	24	96
Totals	5		11		4		11		31	

if the fragments are firmly fixed either by a tibial graft (for the tibia or femur) or by an intramedullary nail (for the humerus)

In all cases, the bones must be surrounded by healthy soft tissue, made possible by the excision of the fibrous tissue This tissue must be replaced, where superficial bones are concerned, by a pedicled skin graft made in a preliminary stage In the case of deep-lying bones, replacement is made in the same stage, by approximating the adjacent muscle tissue

TUBERCULOSIS OF THE SPINE

An Analysis of Cases Treated Surgically*

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This study is based upon 177 consecutive cases of Pott's disease, treated surgically at Sea View Hospital during the six-year period from 1940 to 1945, inclusive. Its primary purpose was to examine the factors affecting the hospital mortality rate in this condition. Only those cases are included in the series in which at least part of the surgery had been done in this institution. Excluded are those cases which were deemed inoperable, those in which the patients refused surgery, and those in which complete surgery had been done at other institutions, and the patients were transferred to Sea View Hospital for convalescent or terminal care.

INCIDENCE OF POTT'S DISEASE

Of the 12,835 tuberculous patients treated at Sea View Hospital during the period covered by this study, only 417 had Pott's disease,—an incidence of 3.2 per cent. This percentage is well below that recorded in the literature. The generally accepted explanation for this reduction in percentage of spine lesions is the gradual disappearance of bovine tuberculosis. Auerbach[1] claims that osseous lesions are related to the primary complex. Due to improved treatment of progressive primary pulmonary tuberculosis, he believes that the period of possible metastasis is shortened and the percentage of bone lesions is reduced[2].

THE HOSPITAL MORTALITY RATE

The mortality rate for the 417 cases of Pott's disease was 55.8 per cent. (233 patients died). Of the 177 patients operated upon, 66 (37.3 per cent.) died; among the 240 patients not operated upon, there were 167 deaths (69.6 per cent.).

Of the patients with all forms of tuberculosis treated at Sea View Hospital, 4,114 died and 8,721 were discharged, the general mortality rate being 32.1 per cent. The mortality rate for the patients operated upon in our series is only 5.2 per cent. higher than this. If we consider that the patients operated upon had more extensive involvement than the average, and, if we contrast the percentages of mortality of those operated upon and those not operated upon, the favorable influence of surgery becomes evident.

FACTORS INFLUENCING THE MORTALITY RATE

Age

The incidence and the death rate in each decade (Charts 1 and 2) are in accord with Cleveland's figures, except that we found the highest mortality rate to be in the sixth decade, whereas it was in the third decade in Cleveland's series. However, like Cleveland, we found that the very young patients did best of all, with a mortality rate of only 14.3 per cent. This figure is offered for the consideration of those who have accepted early fusion as the treatment of choice in Pott's disease in adults, but still hesitate to employ the same method in children. The deceleration of deformity and the increase in the child's life span, provided by surgery, are truly astonishing. Of twenty-four children under thirteen years of age who survived, the average postoperative stay in the Hospital was fifteen and one-half months. Of fifteen children not operated upon, the average hospital

* Read at the Orthopaedic Section of the New York Academy of Medicine, April 1948.

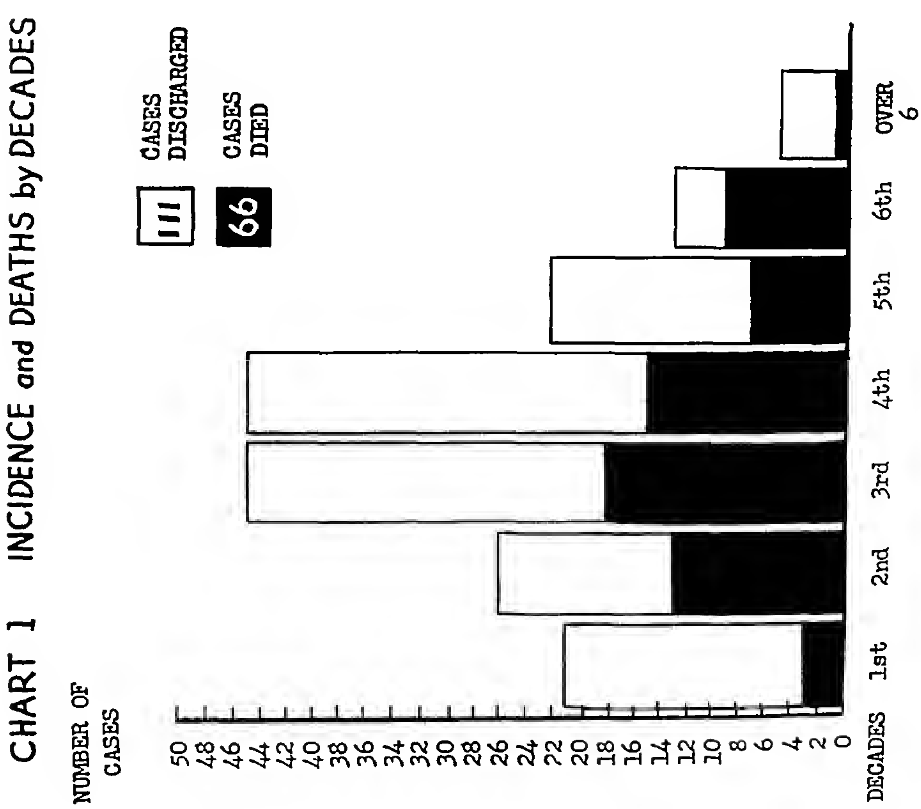

CHART 1

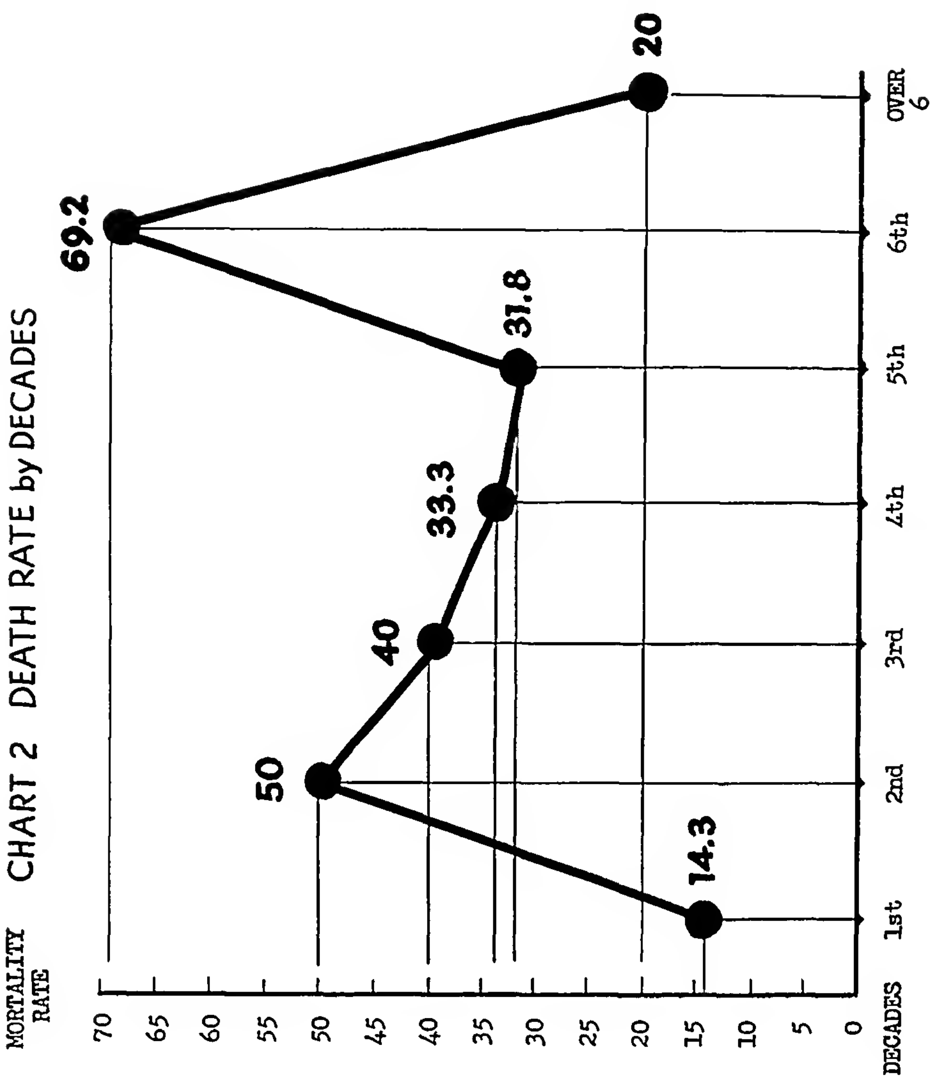

CHART 2

stay in the six-year period was twenty-six and one-half months No child who was not operated upon recovered sufficiently to be discharged

Sex

One hundred and eleven of the patients were males and sixty-six were females,—a preponderance of the male sex which has been observed before Forty-five of the male patients died and twenty-one of the female patients, which gives a higher mortality rate (40 5 per cent) for the males, as compared to the females (31 8 per cent)

Race

Members of the negro race show a definite susceptibility to tuberculosis of the spine While negroes represented only 38 7 per cent of the total admissions to Sea View Hospital, they constituted 221 (53 1 per cent) of the patients with Pott's disease However, only 39 4 per cent of the negroes who had had adequate surgery died (37 of 94 cases), as compared to 34 6 per cent of the white patients (28 of 81 cases) In other words, with comparable surgical care, the negro with tuberculosis of the spine has a chance of survival almost equal to that of the white man

Area of Spine Involved

The distribution of tuberculous lesions of the spine in this series is in agreement with the pattern reported by others In 82 5 per cent of our patients, the lesions were present in the lower thoracic, thoracolumbar, and lumbar regions (Chart 3) No attempt was made to list the number of vertebrae involved in each case The exact extent of the disease can only rarely be determined by clinical or roentgenographic study In twenty-nine cases, more than one of the seven charted areas were diseased, in five of these, more than two areas were affected, and in two instances, the entire spine was involved The more widespread involvement did not seem to affect adversely the mortality figure among the

CHART 3 INCIDENCE and DEATHS by SPINE AREAS INVOLVED

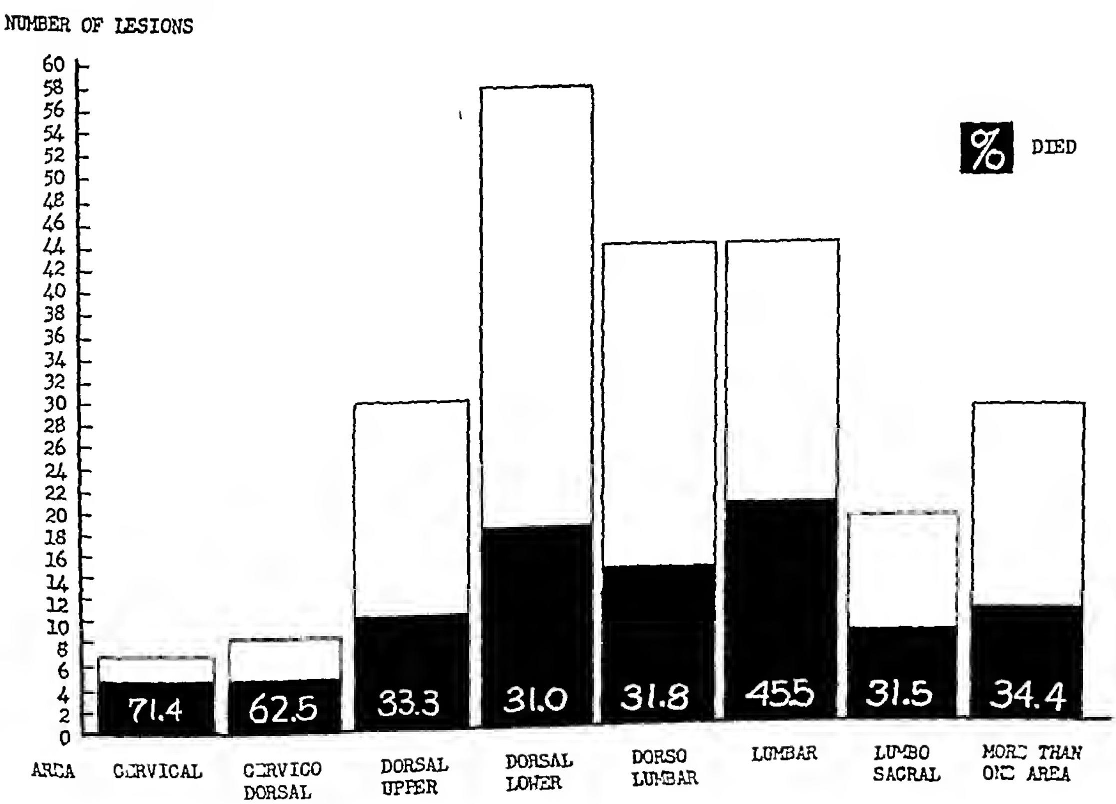

CHART 3

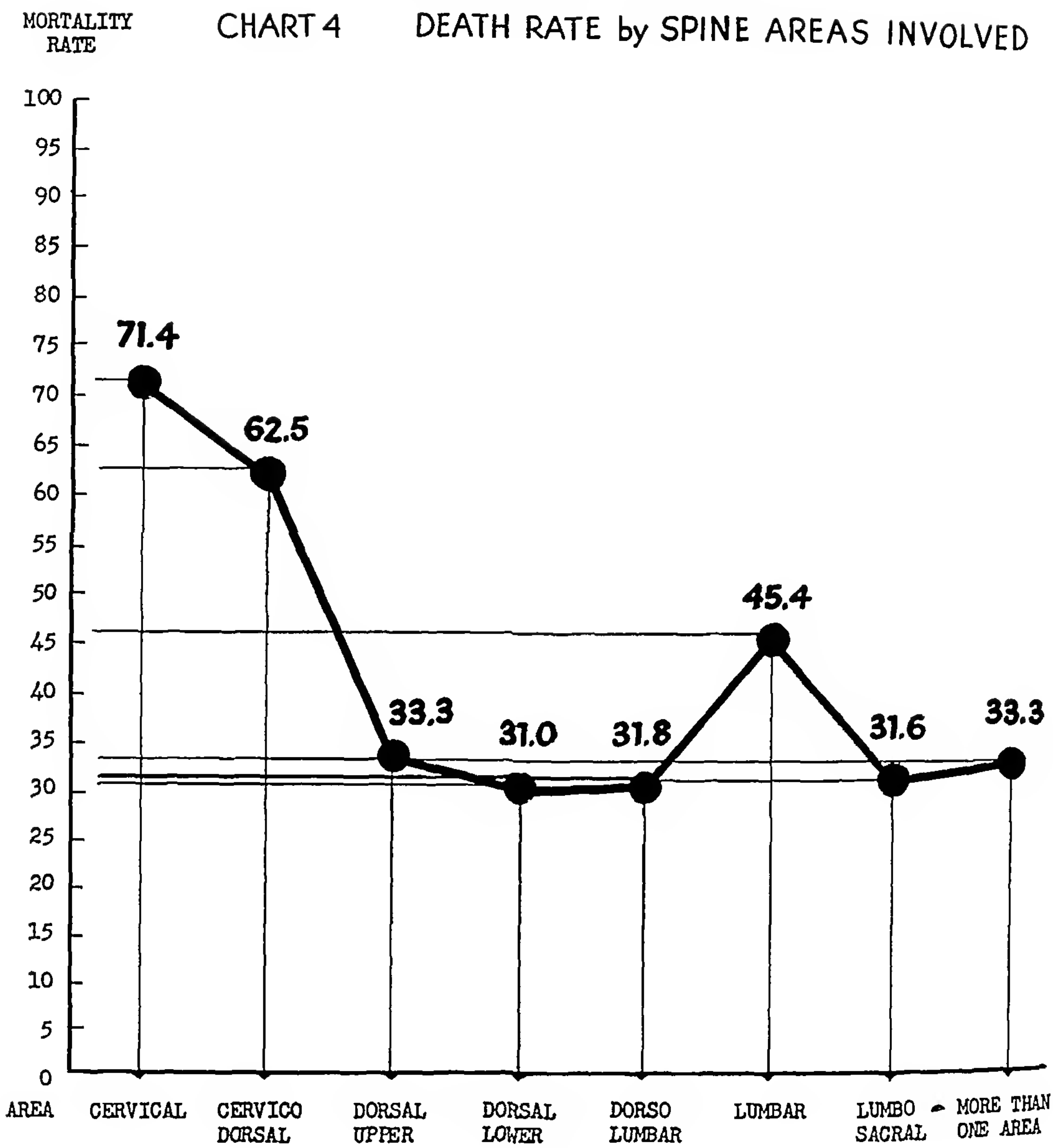

CHART 4

surgically treated patients This observation has also been made by Girdlestone However, unlike Cleveland or Girdlestone, the authors found that disease in the upper (cervical) portion of the vertebral column carried the highest mortality rate (71 4 per cent), the lowest rate (31 per cent) was found in disease of the lower thoracic area (Chart 4)

TABLE I

PATIENTS WITH NEURAL-ARCH DISEASE *

Area of Involvement	Number Died	Number Discharged
Cervicothoracic	1	
Thoracic		
Upper	4	
Lower	7	3
Thoracolumbar	7	2
Lumbar	5	
Lumbosacral		1

* In 22 of 66 patients who died 33 3% incidence
In 6 of 111 cases discharged 5 4% incidence

Fig 1

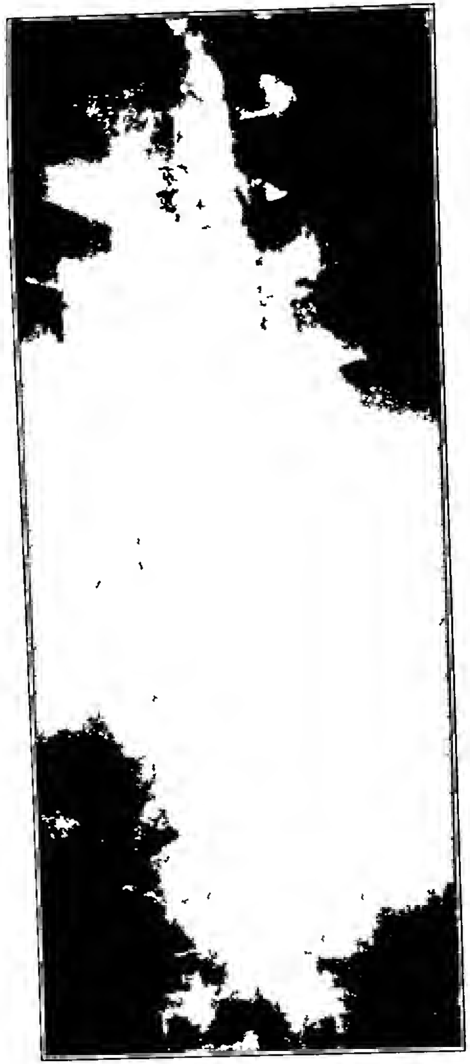

Fig 2-A

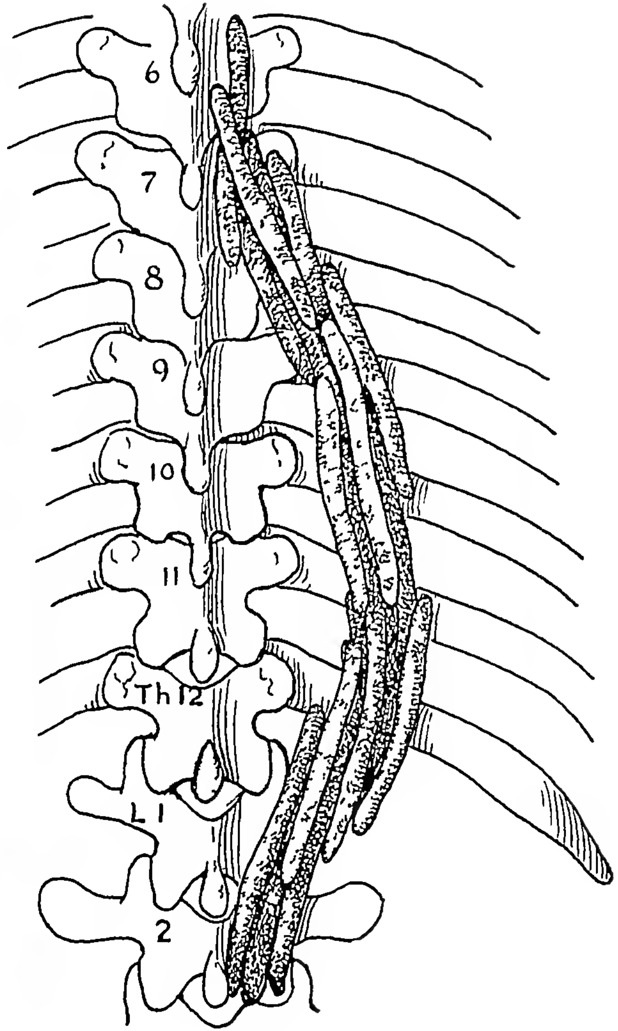

Fig 2-B

Fig 1. Neural-arch disease, such as is evident in this case, is rarely shown by roentgenogram, but may be diagnosed clinically

Figs. 2-A and 2-B. Where sinuses exist in the mid-line and both right and left sides of the neural arches are involved, a circumduction fusion may be done from the sound spinous processes above. The neural arch can be built out around the ribs and back to the sound spinous processes of the neural arch below

TABLE II

SINUSES IN SPINAL TUBERCULOSIS *

Area of Involvement	Number of Cases
Cervical	1
Cervicothoracic	2
Thoracic	
Upper	7
Lower	15
Thoracolumbar	25
Lumbar	13
Lumbosacral	14
More than one area	10

* In 45 of 66 patients who died 68 2% incidence
In 24 of 111 patients discharged 21 6% incidence

Neural-Arch Involvement

It is generally accepted that the posterior elements (neural arches), or so-called small parts, of the vertebrae are seldom involved Although disease in this location is considered a serious problem, a review of the literature has failed to reveal any studies on this subject

The surgical importance of such a lesion is obvious Fusion must be attempted in this region and, if tuberculosis is present, the surgeon works in an infected field, on bone already diseased Statistics from this series of cases prove the seriousness of such involvement (Table I) The neural arches were involved in twenty-eight of the patients,—an incidence of 15 8 per cent Of these, twenty-two died,—a mortality rate of 78 6 per cent

Fortunately, clinical evidence of such involvement sometimes exists preoperatively, as shown by the presence of swelling, abscess formation, or sinus near the mid-line Often it is detected only at operation Rarely is it demonstrable by roentgenogram (Fig 1) It is only when the disease process is well advanced that roentgenographic evidence of involvement of the neural arches can be ascertained definitely

While neural-arch involvement necessitates a guarded prognosis, 21 4 per cent of the patients in this series were discharged on a moderately active regimen, as determined by an average follow-up of three and one-half years It has been the policy of this Service to proceed with fusion when neural-arch disease is not discovered until after surgery has been begun If clinical evidence of such disease is discovered before operation, and if the tuberculous process is confined to one side, a hemifusion is attempted on the opposite side The skin incision in such cases is made well away from the mid-line For the occasional

TABLE III

POSITIVE SPUTUM AND SPINAL TUBERCULOSIS *

Area of Involvement	Number of Cases
Cervical	1
Thoracic	
Upper	5
Lower	14
Thoracolumbar	8
Lumbar	16
Lumbosacral	4
More than one area	5

* In 15 of 66 patients who died 22 7% incidence
In 28 of 111 cases discharged 25 0% incidence

TABLE IV

OTHER SKELETAL FOCI OF INFECTION *

Foci	Died	Discharged	Total
Elbow	10	3	13
Knee	7	3	10
Foot and ankle	4	5	9
Sternum	4	3	7
Hip	2	4	6
Shoulder	4	1	5
Wrist	2	3	5
Fingers	3	1	4
Sternoclavicular joint	3	0	3
More than one focus	11	1	12

* In 29 of 66 patients who died 43.9% incidence
In 22 of 111 cases discharged 19.8% incidence

case in which neural-arch involvement is bilateral, yet the patient's general condition remains good, a variant of the fusion procedure has been devised. Hemifusion with iliac strips is done in stages, building from sound spinous and transverse processes above the tuberculous area outward onto the ribs (Figs. 2-A and 2-B). This reconstruction is carried downward onto the ribs, and then inward to the spinous processes below the diseased area. Such a fusion can be successful even in the presence of mid-line sinuses.

Sinuses

In sixty-nine of the patients operated upon (38.9 per cent.), mixed-infection tuberculous sinus tracts were present. Of this group, forty-five patients (65.2 per cent.) died during their hospital stay. Thus, the presence of a sinus is a grave finding. In this series there was no preponderance of sinuses from any area. The distribution closely paralleled that of the tuberculous lesion, with the greatest number appearing in the thoracolumbar area (Table II). As in fractures, compounding the lesion adds great hazard. Healing may occur and may be permanent, but a potential explosive element remains. When the sinus persists, serious complication is to be expected. Streptomycin seems to be changing the picture, but the study of its effectiveness is not yet complete.

Pulmonary Tuberculosis

There was a surprising lack of correlation in this series between a history of active pulmonary tuberculosis with positive sputum and the mortality rate. Of the 177 patients operated upon, forty-three (24.3 per cent.) had had active pulmonary tuberculosis with

TABLE V

NON-SKELETAL EXTRAPULMONARY FOCI *

Source of Infection	Died	Discharged	Total
Genito-urinary	11	7	18
Cervical adenitis	6	3	9
Gastro-intestinal	8	0	8
Soft-tissue foci in extremities	1	3	4
Peritonitis	2	1	3
Larynx	1	1	2
More than one area	2	2	4

* In 26 of 66 patients who died 39.4% incidence
In 13 of 111 cases discharged 11.7% incidence

positive sputa or gastric washings (Table III) The mortality rate in this group was 34 9 per cent, which is 2 8 per cent more than that for the series as a whole

Cleveland believed that joint tuberculosis in patients with pulmonary lesions and positive sputa had an unfavorable prognosis exceeded only by metastatic spread to other organs The success now achieved must be credited to the great advances in control of pulmonary tuberculosis

Other Bones as Foci of Infection

In fifty-one (28 8 per cent) of the cases, the spine was only one of several bone foci present Of these patients, twenty-nine (56 9 per cent) died There were twelve patients with more than one extraspinal bone focus, and of these, only one survived,—a mortality rate of 91 7 per cent The survivor was a young woman in excellent general condition with involvement of only the ankle and talonavicular joint on the same side Fusion was successful in both of these joints, as well as in the spine A ten-year follow-up on normal activities was made in this case

An unexpected finding was the distribution of the extraskeletal bone foci The site most frequently involved was the elbow, next in order of occurrence were the knee, foot and ankle, sternum, and hip (Table IV)

Non-Skeletal Extrapulmonary Foci

Of thirty-nine patients with other extrapulmonary foci, twenty-six or 66 7 per cent died (Table V) This figure bears out Cleveland's contention that patients with complicating organic foci have a poor prognosis The genito-urinary tract was affected in eighteen patients (10 per cent) Other writers[1, 6] have found higher proportions

Amyloid Disease

Positive proof of amyloidosis was found in twenty-seven patients (15 2 per cent) All but one died,—a mortality rate of 96 3 per cent The one patient who was discharged had repeated 100 per cent Congo-red absorption She disappeared after a follow-up of two and one-half years, apparently well, but on limited activity

SUMMARY

1 In tuberculosis of the neural arch the prognosis is poor, but fusion is often successful

2 While negroes appear more susceptible to tuberculosis of the spine than white patients, they have an equal chance for recovery when offered adequate surgery and care

3 Children with Pott's disease progressed unfavorably under conservative care at Sea View Hospital, but presented the greatest and most rapid recovery rate in the whole series when fusion was done

4 Pulmonary tuberculosis, when controlled by modern methods, does not appear to affect the prognosis in the patients operated upon

5 Amyloid disease accompanying tuberculosis of the spine is practically always fatal

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SPONDYLITIS, PATHOLOGICAL OSSIFICATION, AND CALCIFICATION ASSOCIATED WITH SPINAL-CORD INJURY *

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The many problems of injury to the spinal cord have been the subject of recent investigation. The bones, ligaments, soft tissues, and joints may be affected by permanent damage to the spinal cord. Neuropathic joint changes were commented on as early as 1831 by Mitchell, and in 1868 by Charcot. Calcifications and ossifications in the soft tissues, chiefly about the hips, have been noted by many writers, including Voss, Brailsford, Soule, and Heilbrun and Kuhn, who also studied erosive bone changes about the trochanters. This paper emphasizes another phase of abnormal bone and joint physiology,—a spondylitis similar in many respects to the rheumatoid type, with frequent involvement of the diarthrodial joints. The relationship of these changes to spinal-cord injury prompted this study.

Thirty-five cases of injury to the spinal cord were studied. Of this number, twenty-four patients had complete transverse lesions, six showed partial lesions above the first lumbar segment, and five had lesions of the cauda equina. The ages of the patients varied from eighteen to fifty-five, with an average of twenty-eight years. Only four patients were over forty years of age. The average time from injury until admission to this Hospital was seventeen months, ranging from two to seventy-six months. The average hospital stay until discharge, transfer to another center, or death, was eight months, ranging from one to thirty-four months.

LABORATORY FINDINGS

Twenty cases of complete lesions of the spinal cord were selected for determination of the blood-serum calcium and phosphorus, blood chlorides, serum proteins, and the qualitative urinary-calcium excretion (by the Sulkowitch test). Serum acid and alkaline phosphatase were determined in eight cases (by the King-Armstrong method). The acid phosphatase was within normal limits and the alkaline phosphatase was elevated to twenty-three units in only one instance, associated with hepatitis and jaundice. Blood-calcium values ranged from 7 to 12.2 milligrams per 100 cubic centimeters, with an average of 10.4. Blood-phosphorus values averaged 3.5 milligrams per 100 cubic centimeters, with a range of 1.9 to 4.3. The Sulkowitch test showed one to four plus excretion in all cases except two. The blood chlorides were below 400 milligrams per 100 cubic centimeters in nine of these patients. The serum proteins averaged 6.6 grams per 100 cubic centimeters, with a range from 4.8 to 7.8.

ROENTGENOGRAPHIC FINDINGS

Roentgenographic survey included the vertebral column, pelvis, and the hip region. (Discussion of the fracture or site of injury is intentionally omitted.) The bone changes and the level of the injury to the cord were correlated, and two groups were established. Group A included lesions below the first lumbar vertebra and all partial lesions, irrespective of site, since the roentgenographic findings in these two types revealed little essential difference; Group B included all complete transverse lesions above the first lumbar segment.

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Fig 1-A

Soft-tissue ossifications and calcifications

Fig 1-A January 18, 1946 A white male, twenty-six years old was injured in August 1943, by a fall from a three-story building, and suffered a transverse lesion of the cervical cord Oblique cysto-urethrogram demonstrates fibrositic calcification of the soft tissue of the buttock Apophyseal- [illegible]

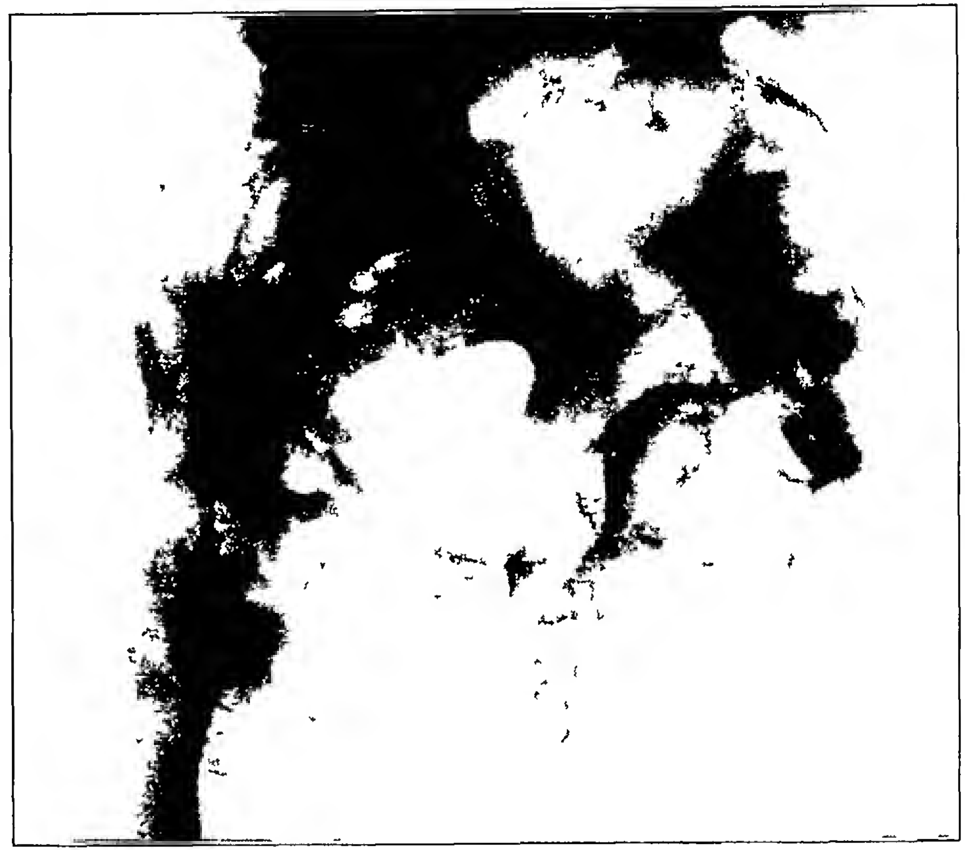


Fig 1-B

Fig 1-B January 21, 1946 A white male, forty-two years old, was struck on the back in August 1943 The lesion was at the level of the first lumbar vertebra Periosteal new-bone formation can be seen, extending upward from the region of the greater trochanter The upper portion has the appearance of solid bone Some increased density of the acetabular rim is present, although the joint space is not involved

Fig 1-C May 21, 1945 A white male, twenty-five years old, was injured in May 1943, by a bullet which severed the spinal cord at the level of the third thoracic vertebra Periarticular calcific changes about both hips are seen, with capsular involvement on the right There is a bony exostosis, arising from the anterior margin on the left Small areas of calcific deposits are seen in the soft tissues There is a marked increase in the density of the pelvic bones, and the sacro-iliac joints are almost completely obliterated

Fig 1-C

Fig 1-D

Fig 1-D June 27, 1945 A negro male, twenty-eight years old had a complete transverse lesion at the ninth thoracic segment, secondary to a bullet wound Periosteal bone formation is seen about the region of the left hip The bones of the pelvic girdle have a sclerotic appearance and there is obliteration of the sacro-iliac joints Lacy and bizarre arrangement of periosteal new bone is present There [illegible] osit calcific deposits about the region of the right hip

In Group A, the findings were not significant. There were six partial lesions above and five below the first lumbar vertebra. One case was excluded from the analysis, because no roentgenogram was obtained of the lumbar spine or pelvis. In seven of ten of the remaining patients, changes were evident in the sacro-iliac joint, manifested by narrowing or partial fusion. Otherwise, the pelvis was negative in four patients, and osteoporosis was present in six. Fusion of the apophyseal joints occurred in two patients. The lumbar spine was otherwise negative in five and osteoporosis was present in five patients. No other ligamentous or soft-tissue changes were observed in this group.

In Group B, the findings were more striking, and represented a more advanced stage of the disease process. There were sixteen low-thoracic lesions, five upper-thoracic lesions, and three cervical lesions. The pelvis was negative in two cases, with osteoporosis in fourteen, marked sclerotic changes in only three, and a combination of sclerosis and osteoporosis in five. Of primary interest were the sacro-iliac joints, in all but three of which some degree of sclerosis was manifest, varying from partial to complete fusion. Complete fusion occurred in eight patients, in four of whom it was bilateral. Some degree of sclerosis was noted about the acetabular margins. Other findings included lacy periostitis of both ischia, a narrowed symphysis pubis, and streaky calcifications in the buttocks.

Roentgenographic findings in the lumbar spine showed that the apophyseal joints were involved in fifteen cases, with a varying degree of fusion. Osteoporosis of the bodies was present in twelve, sclerosis in six, and a combination of the two in four patients. The bodies were negative in two patients. Rather marked sclerosis of the bodies of the fifth lumbar and the first sacral vertebrae was present in nine patients. Calcification of the paraspinal ligaments occurred in only two patients.

Of particular interest were the proliferative bone changes and soft-tissue calcifications about the hip joints and the upper portion of the femur, seen to a varying degree in seven patients in this series. There was no definite period of time between the trauma and the roentgenographic manifestations, although most of these patients were seen one to two years after injury.

COMMENT

A variety of bone lesions occur in the paraplegic patient (Figs. 1-A through 1-D). The soft-tissue ossifications and calcifications about the hip are of frequent occurrence, but they follow no similar pattern. Thus, exostoses may arise from the acetabular margin, or periosteal new-bone formation may be present. New-bone formation or calcification may occur in the muscles or fascia. The appearance may be like that of solid dense bone or it may have a striated appearance. Proliferative bone changes may occur in the tendons or joint capsules, and, in the latter, may lead to ankylosis. The joint space, however, is usually uninvolved.

No evidence of the neuro-arthropathies was seen in this series, probably because of the relative infrequency of weight-bearing and increased recumbency. Soule stated that the changes are most prominent about the tibial collateral ligament. He observed no ossifications anterior or posterior to the knees in his series. Heilbrun and Kuhn described the erosive bone changes in the region of the greater trochanter, secondary to decubitus ulcers, as "first, erosive changes leading to loss of the normal contour of the trochanters with flattening, followed by reshaping or molding, and later repair of the eroded surface with formation of an abnormal contour by proliferative or exuberant bone. . . . Pathologically this is evidenced by a subacute and chronic infection of the tissue overlying the bone, with extension to the superficial layers of bone. This leads to resorption of the cortex and underlying trabeculae. The bone marrow is replaced by fibrovascular tissue which accompanies the low-grade inflammatory process."

The involvement of the sacro-iliac and apophyseal joints and the spinal ligaments is merely one phase of the over-all disease process. The similarity between this form of

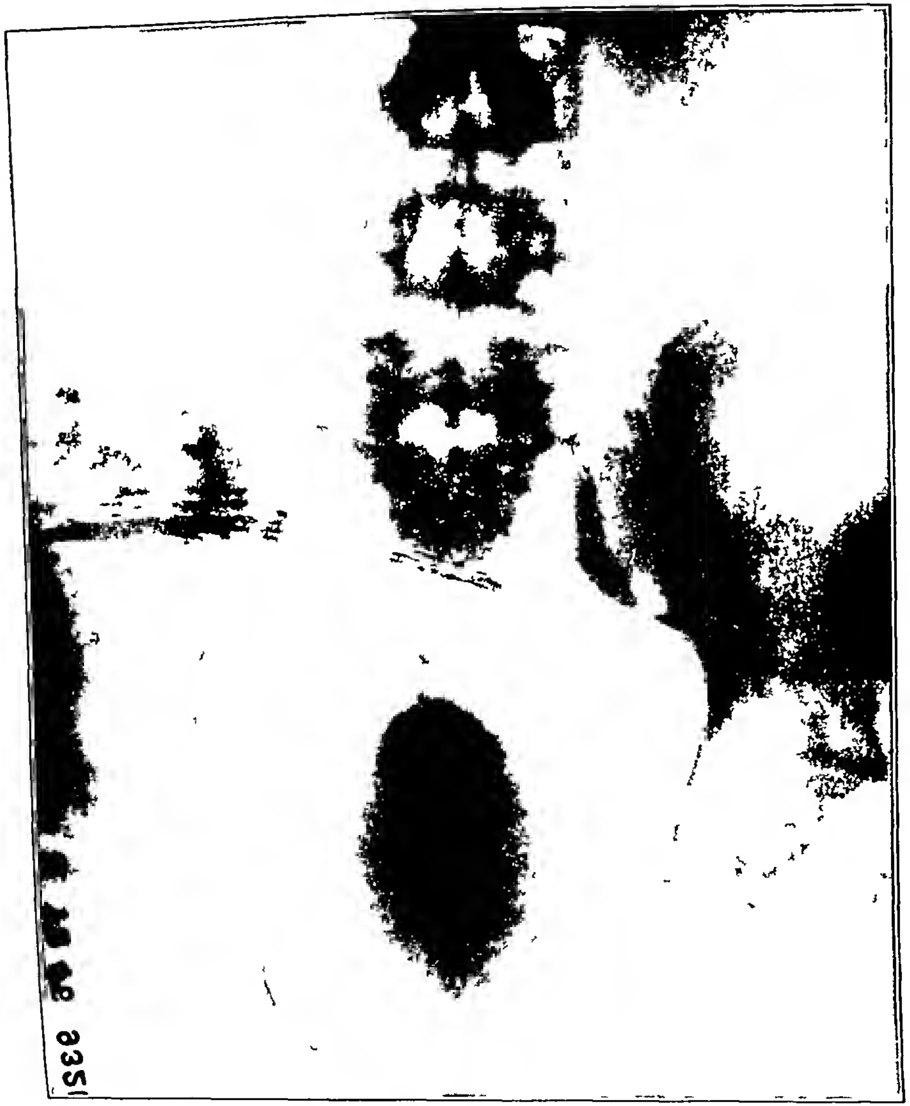
spondylitis and rheumatoid spondylitis is evidenced by involvement of the small posterior intervertebral articulations and the sacro-iliac articulations, the atrophy of the bodies, and the calcifications of the interspinal ligaments. Certain differences are evident. Despite the level of the cord injury, no instance was seen of involvement above the lumbar spine. Although osteoporosis was the predominant finding, it may be accompanied by densification. The paraspinal ligaments are more commonly involved in rheumatoid spondylitis.

The changes observed in this group of paraplegic patients include exostoses, diarthrodial-joint and ligament changes, massive soft-tissue ossifications and pathological deposits of calcium, and sclerosis and osteoporosis of the pelvis and vertebrae. In these patients, the importance of the neurotrophic lesion is apparent. Eloesser and Repetto have added to the knowledge of the pathogenesis of the neurotrophic joint. By animal experimentation they were able to prove that, in addition to loss of joint sensibility, repeated traumata were necessary to produce the typical joint changes. The neurotrophic lesion and repeated traumata play an important part in the production of the extensive soft-tissue calcifications or ossifications. Whether or not the mechanism of pathological calcification is due to disturbance in fat metabolism, changes in the pH of tissues, phosphatase activity, secondary hyperparathyroidism or circulatory changes, or to a combination of these factors, is not definitely known.

Klotz demonstrated antecedent fat changes in the affected areas with insoluble compounds replacing soluble ones, particularly with an excess of calcium. Robison emphasized the importance of phosphatase in pathological calcification. He found that this enzyme was richest in ossifying cartilage and, to a lesser degree, in the kidneys. In affected tissues there is hydrolysis of the ester and liberation of inorganic phosphate. The increased concentration of phosphate results in the precipitation of carbonates. Gomori, however, has demonstrated that calcification of hyalinized connective tissues occurs without any phosphatase activity, but that living or recently necrosed tissue seems to involve phosphatase activity.

Wells believed that, in areas of tissue degeneration, deposition of calcium salts is dependent upon increased alkalinity or decreased carbon dioxide. He suggested that calcium salts are held in solution by proteins, either as carbonate or phosphate or as calcium-ion protein compounds, or both. This delicate balance is capable of being overthrown by alkalinity, changes in protein or carbon dioxide, or changes in the quantity or composition of the calcium salts. Vaughan and his associates stated that there is a tendency for precipitation to occur with marked changes in the pH of the media, or when increased phosphatase is present. Precipitation with normal blood levels may take place from non-colloidal ionic solutions. When hypercalcaemia is present, precipitation occurs from colloidal suspension of calcium-phosphate-protein complex. In renal disease, Schmidt pointed out that the increased albumin and phosphate excretion affected the calcium balance. These substances ordinarily act as buffers to keep calcium in solution. With chronic renal disease, the production of secondary hyperparathyroidism is another possible etiological factor. Pappenheimer demonstrated hyperplasia of the parathyroids in nephritic conditions. He showed that reduction of renal tissue in young rats resulted in an increased volume of the parathyroids. In addition, when these rats were placed on a low-calcium diet, rachitic changes occurred in the bones. With a moderate-calcium diet, the changes were in the direction of osteitis fibrosa. Soffer and Cohn, in discussing secondary hyperparathyroidism, found that such cases were not characteristic. There may be hyperplastic glands with or without bone changes, or bone and chemical changes with histologically normal parathyroid glands. The demand for calcium apparently is increased, although the exact mechanism is uncertain.

From a pathological standpoint, the explanations advanced by Leriche and Policard and Watson Jones and Roberts, based on the importance of circulatory disturbances, offer a reasonable explanation for the multiple changes observed in these individuals. Thus, hy-



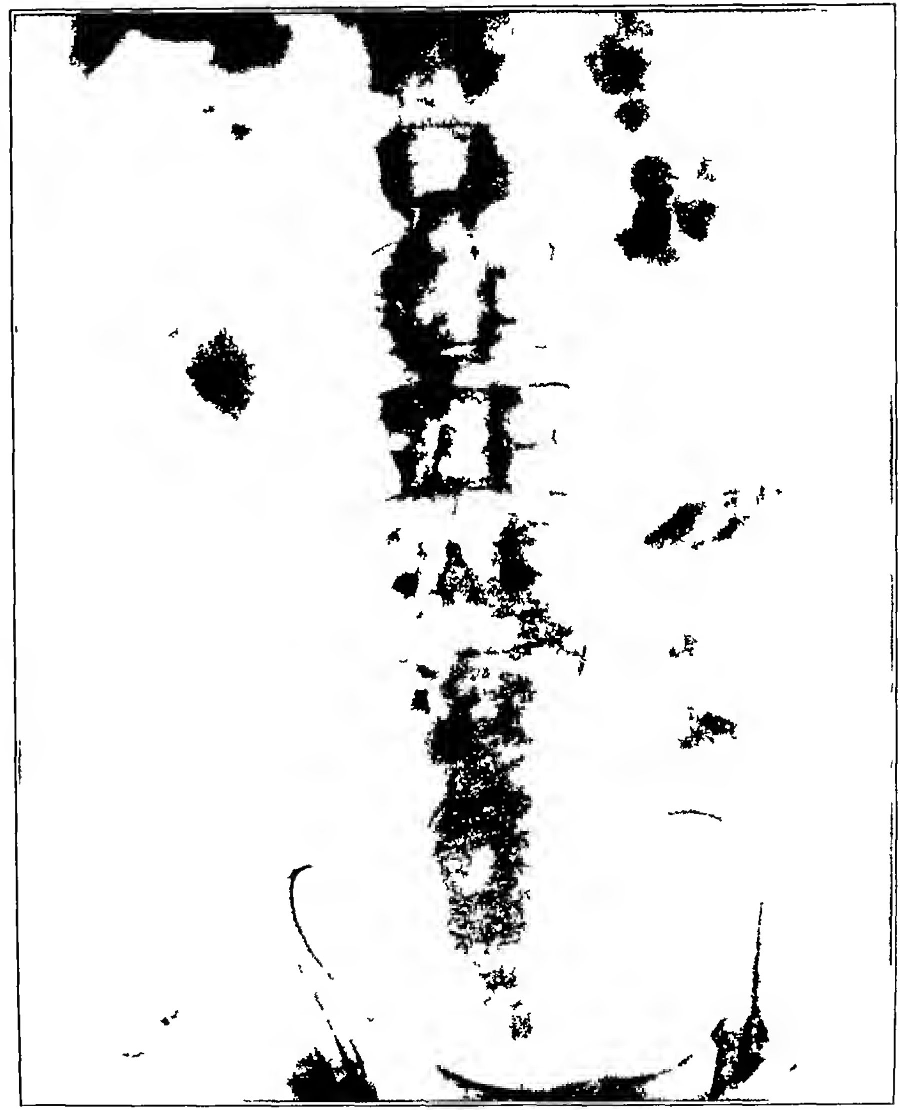


Fig 2-A Sacro-iliac and apophyseal-joint changes Fig 2-B

Fig 2-A *Early changes* February 18, 1946 This white male, nineteen years old, was injured in April 1944, by a twenty-foot fall and suffered complete transection of the spinal cord at the seventh thoracic segment Pyelocysto-urethrogram illustrates narrowing of the sacro-iliac joint with haziness and increased density surround-

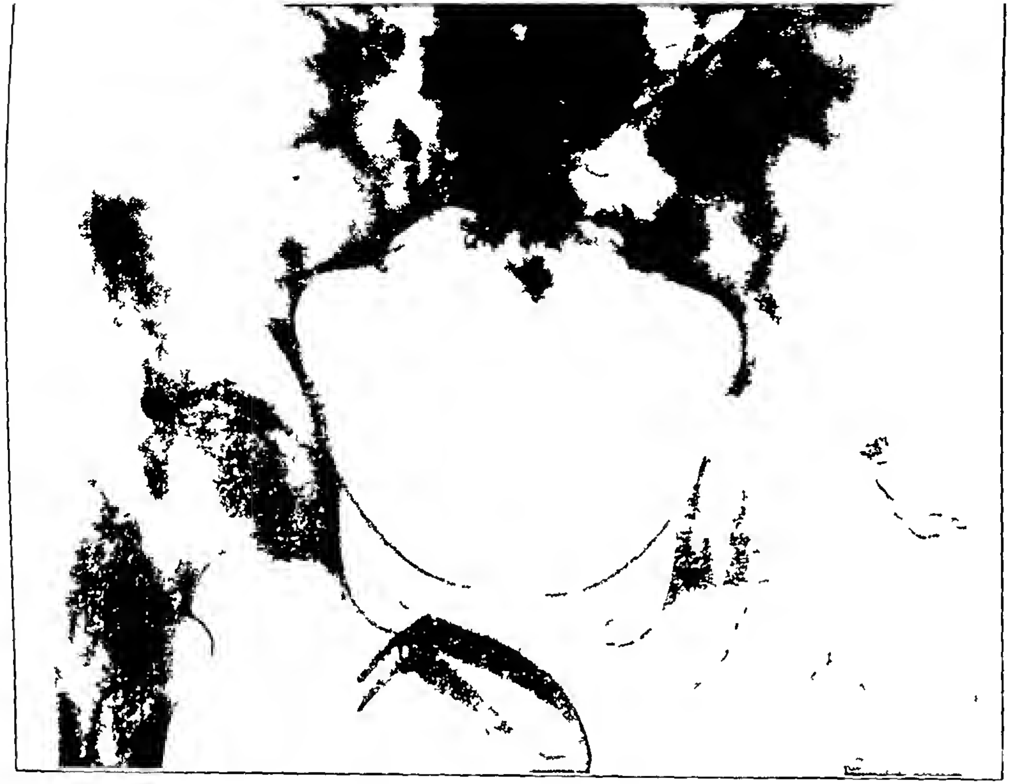


Fig 2-C

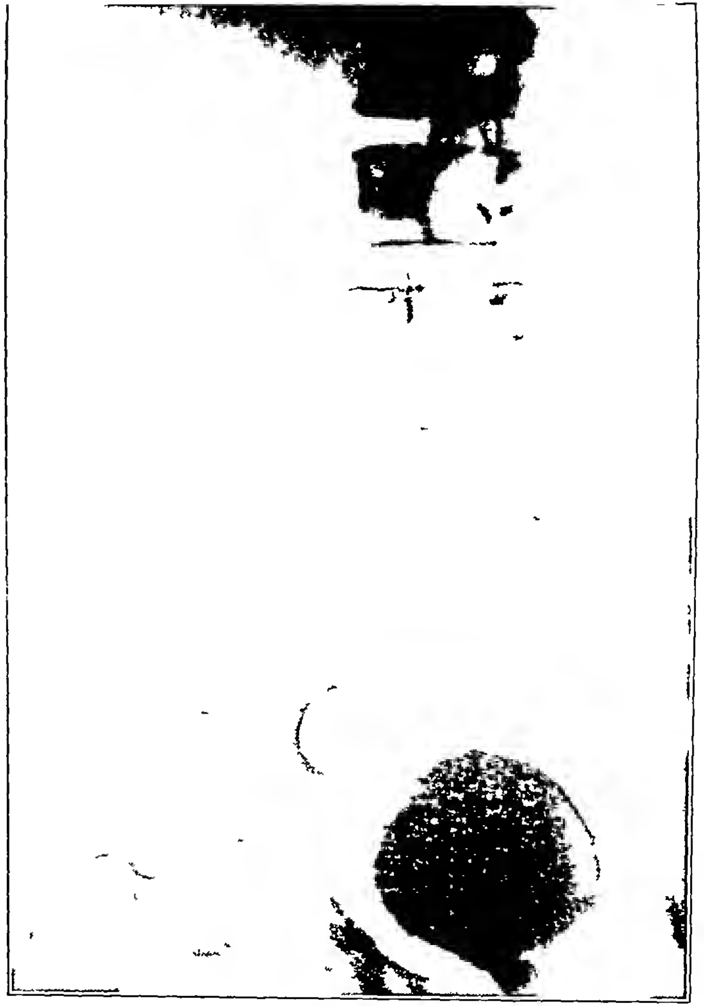


Fig 2-D

Fig 2-A (*Continued*) ing the joint margin Sclerotic changes of the apophyseal joints are also present, with complete obliteration of the joint between the fourth and fifth lumbar vertebrae Scattered areas of increased density of the vertebrae are seen

Fig 2-B *Moderately-advanced changes* November 28, 1945 This white male, twenty-four years old, was struck on the back by a falling tree in December 1943, and suffered a complete transverse lesion at the level of the twelfth thoracic vertebra Intravenous pyelogram reveals further narrowing and increased density There is bony fusion of the upper half of the left sacro-iliac joint This area assumes the trabecular pattern of bone The apophyseal joints show obliteration and narrowing

Fig 2-C *Far-advanced changes* May 13, 1946 A white male, forty-six years old, suffered a complete lesion at the level of the tenth thoracic vertebra, as the result of an automobile accident in November 1943 A roentgenogram shows complete obliteration of the sacro-iliac joints Osteosclerotic changes of the pelvis and osteoporosis of the femur are present

Fig 2-D *Apophyseal-joint changes* January 22, 1946 A white male, twenty-three years old, was injured in May 1944, by a shell fragment, and suffered a complete lesion at the level of the eleventh thoracic vertebra An oblique cystogram demonstrates narrowing of the apophyseal joint between the fourth and fifth lumbar vertebrae, with irregularity of the joint margin Coarse trabeculations are seen

Fig 2-A

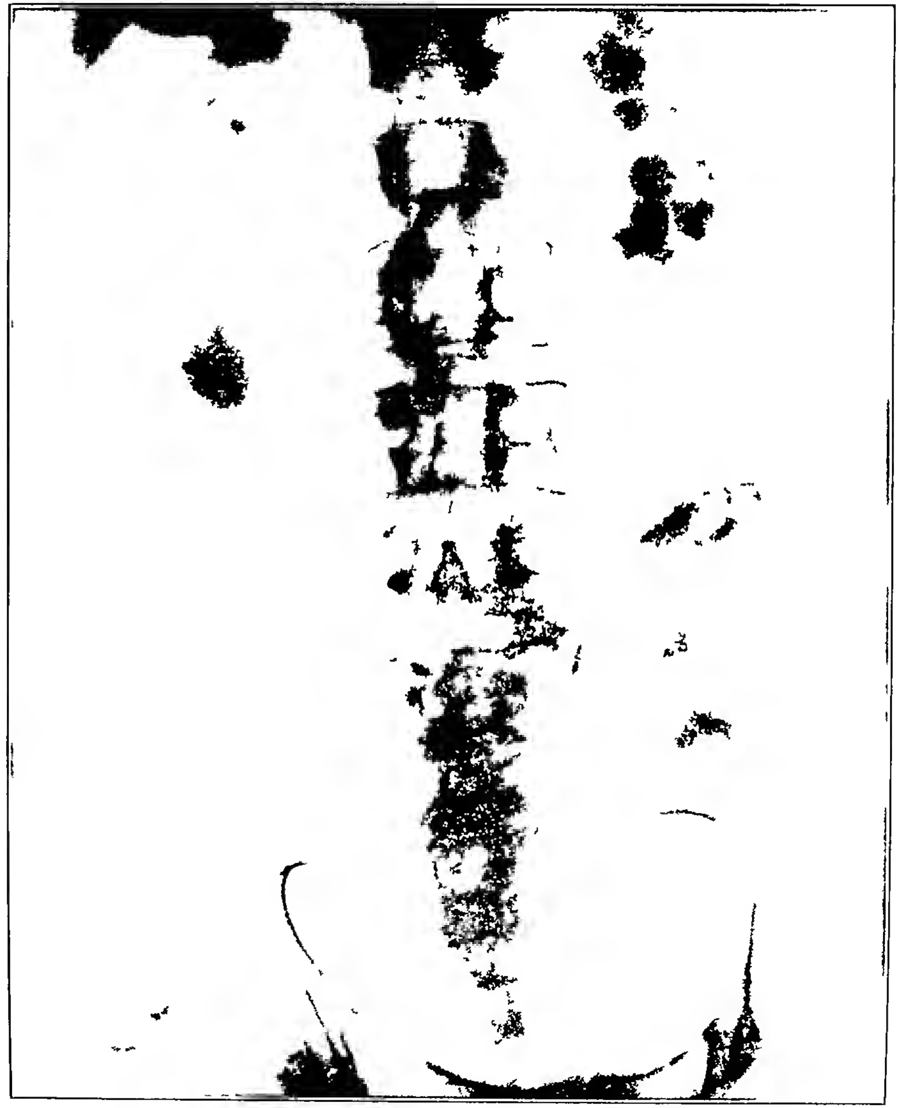


Fig 2-B

Sacro-iliac and apophyseal-joint changes

Fig 2-A *Early changes* February 18 1946 This white male nineteen years old was injured in April 1944 by a twenty-foot fall and suffered complete transection of the spinal cord at the seventh thoracic segment Pyelocysto-urethrogram illustrates narrowing of the sacro-iliac joint with haziness and increased density surround-

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MYOSITIS OSSIFICANS IN PARAPLEGICS

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At the end of World War II, a large number of paraplegic patients had to be treated at the various paraplegic centers throughout the United States. As a result of excellent care, these patients are now living longer than the average patient of several years ago, and some are presenting unusual complications. The authors have compiled data concerning one of these complications, as well as meager material which has been culled from the literature.

Myositis ossificans was recognized more than two hundred years ago. Until after World War I, however, practically nothing was written about the occurrence of this disease in transverse lesions of the spinal cord. The principal reports in the literature have been recorded by French neurologists. After World War I, they followed a considerable number of these patients from an orthopaedic as well as from a neurological standpoint and presented some of the earliest descriptions of myositis ossificans in the paraplegic patient.

In 1919, Dejerine, Ceillier, and Dejerine presented a paper to the *Societe de Neurologie* of Paris on the anatomical and histological study of para-osteo-arthropathies in cord lesions They stated that para-osteo-arthropathy has certain points of predilection The first area is about the medial femoral condyle Dense compact tissue is formed, which may be a single mass or may have an apparent extension along the femoral shaft This diaphyseal extension, however, is a fine lacework of bone described as being "*soufflees*" Second, the condition is found about the hips, but never above the pelvis or below the knees The incidence of this lesion was found by Dejerine and her co-workers to be 48 7 per cent They also stated that the lesions make an early appearance and undergo rapid evolution to variable size There was complete integrity of the articular skeleton, except in one case, in which they found this condition concomitant with evidence of osteo-arthritis The type of tissue at the various sites of predilection was quite constant, they found no evidence of infection or hemorrhage in the area of calcification, nor was the calcification found in decubitus ulcers or scars

Since 1919, many articles have been written on myositis ossificans resulting from trauma, but not in reference to cord lesions Geldmacher, in 1925, wrote an article on the subject of myositis ossificans in cord lesions, which was referred to by Frejka in 1929 in his case study of progressive myositis ossificans In 1943, Hanke, in Germany, wrote an article on myositis ossificans circumscripta neurotica in paraplegics following vertebral fracture Stanger, in 1946, reported the complication in two cases of paraplegia He describes this condition as ossification of the pelvifemoral muscles following fracture-dislocation of the thoracolumbar region of the spine, sustained in coal-mine accidents near Leeds, England The ossification became evident six months after injury, but the masseuse had noted increased resistance to passive flexion at four months One patient showed no other ossification The other patient later had kidney calculi and some involvement of the knee joint

Frejka, in his report of progressive myositis ossificans, mentions Geldmacher's study, in which the knee and hip joints were involved at a very early date after cord trauma Para-articular bony layers appeared, "partly adjacent to the periosteum, partly lying free in soft parts" He reported that development was fully attained within eight months, and that the condition remained static thereafter Frejka further states that "The new bone formation is always primary Neither hemorrhages, inflammatory changes, necroses, or new vessel formation have been observed"

These are the observations which have been made in the past on myositis ossificans in paraplegics, our observations have many points in common with them The sites we have seen most frequently involved are the hips, the upper third of the thighs, and the knees Involvement of the knee has not been frequent, but the ossifications seem to be similar in type to those described by Dejerine at the medial femoral condyle The mass in the thigh is palpable and is usually very firm or hard and indurated It is fixed and follows along a muscle group from the pelvis to the thigh, either anteriorly or medially If the mass is large, the size of the thigh is increased Hip motion is usually limited, however, in only one case thus far has surgery been necessary to free the hips, in order to permit the patient to be mobile in a wheel chair The pelvis and lower extremities show marked osteoporosis and, with the severe spasms, the hip may be dislocated or the femoral neck fractured Urinary calculi are often seen in these patients In fact, the myositis ossificans is frequently an incidental finding on a "scout film" for kidney calculi

Often these patients lie prone in bed for long periods of time, while plastic surgery is carried out on their decubitus ulcers, thus placing pressure continually on the anterior portion of the thighs The patients are moved frequently by attendants, and they get in and out of wheel chairs, automobiles, bathtubs, and carts by themselves, putting traction and strain on soft parts of paralyzed, anaesthetic limbs There is also the passive motion of physical therapy, combined with heat and massage, performed in a gentle yet manipulative manner Some paraplegics have ossification in one area of predilection, but seldom in

all three areas of predilection. We have felt that the lesion appears as Dejerine and her associates describe, but we have not seen nearly so high an incidence (48.7 per cent.) as they report. In this institution there has been a continual turnover of patients, with the constant number remaining around 289 patients, yet we have never seen more than twelve cases of typical myositis ossificans during any three-month period.

Classification

The authors have accepted the classification of Noble, as quoted by Golden.

1. *Myositis Ossificans Progressiva*

This disease begins soon after birth and is characterized by congenital microdactylia, or at least by short first digits of the hands and feet. There is apparently a metamorphosis of muscle into bone, all of the skeletal muscles becoming involved progressively. Death may occur from involvement of the diaphragm and the abdominal muscles.

2. *Myositis Ossificans Circumscripta Resulting from Local Trauma*

This is called muscular osteomata and usually develops late in life, possibly due to occupational injury. The disease process is localized to one site of repeated injury,—for example, the adductor longus ("rider's bone") or the brachialis ("fencer's bone").

Another local ossification following a single trauma belongs in this group. History has been obtained of a severe contusion, a dislocation, or a tangential bullet wound to the bone. The condition may also develop in the muscles of the abdomen after surgery. This is the most common type of myositis ossificans and may become a surgical problem. The injury in this type is recent, but the pain seems to continue beyond the time that it would normally be present. In about three to five weeks, a deep-seated fixed swelling is palpable at the injury site, and roentgenograms reveal a calcium shadow in the region of the muscle. The swelling may extend down to bone and become attached. This type is often confused with sarcoma, but it follows a muscle pattern, never shows erosion of the bone shaft, and is parallel to the shaft.

3. *Myositis Ossificans Circumscripta without History of Trauma*

The condition is usually an incidental finding during examination of the patient or of his roentgenograms. This group includes the myositis ossificans circumscripta neurotica which is discussed in this paper and recorded by Geldmacher, Frejka, and Dejerine. It is a para-articular ossification, associated with cord lesions. Also included in this group are the tabetic osteo-arthropathies and the soft-tissue calcification which occur in these patients from very minor trauma, such as hypodermic-needle punctures. Rough handling of anaesthetic joints may be the source of trauma in these cases.

Frejka would include a fourth group in which, after muscle or joint inflammation, as in rheumatoid arthritis or rheumatic fever, there may be associated ossification of muscle and soft parts.

Blood-Chemistry Findings

The blood-chemistry studies on these patients are disappointing. It seems unusual that, with widespread osteoporosis and local osteogenic reaction occurring in such cases, some evidence of universal change is not detectable in the blood. Significant changes must be occurring, but not enough to alter the blood chemistry.

Frejka, in his cases of myositis ossificans progressiva, found no chemical changes or any mineral imbalance to account for the widespread sclerosis. He reports that many authors have investigated this problem, yet failed to find changes of significance. Stinger, in his report of two cases, revealed no calcium, phosphorus, or phosphatase changes.

The authors' studies on blood calcium, phosphorus, and phosphatase (Table I) showed nothing of significance. The calcium was well within the normal range, as were the

phosphorus and alkaline phosphatase The entire blood picture failed to show any alteration According to Best and Taylor, calcium-balance studies in some instances have revealed calcium retention with values of blood calcium and phosphorus that are normal

Roentgenographic Findings

The roentgenographic findings in these patients are fairly obvious Noble describes the shadows in myositis ossificans circumscripta traumatica as first being mottled and later homogeneous Stripes and spots appear which correspond to muscle bundles and fascial planes Stanger's films reveal a similar picture The ossification is principally around the hips, as in our cases

The authors' earlier roentgenograms were kidney, ureter, or bladder films, taken for genito-urinary calculi The calcifications in the hips, as seen in these films, were incidental findings and were usually the first indication of musculoskeletal abnormality The dense calcifications are about the hips, although several films show minor changes about the knees The hip joints appear fairly normal, but they are somewhat obscured by the calcification, which is dense and trabeculated It most commonly extends anteriorly from the anterior superior iliac spine over the hip joint and along the rectus femoris, either in addition to this course or as an alternative, it may descend medially from the iliopubic rami into the adductor muscle group There may be a variable number of spurs, bands, or bridges of dense calcification from the trochanteric region of the femur to the acetabulum, ilium, or ischium In Figures 1-A to 3-C, inclusive, which show progressive development of the myositis, diaphyseal calcification and knee involvement are illustrated

Pathological Findings

The authors have obtained pathological specimens as well as seemingly normal tissue from the one patient operated upon The anatomical and histological pathology was well described by Dejerine, Ceillier, and Dejerine, in 1919 The specimens which they presented were obtained from eleven patients, involving sixteen joints, and we have taken

FIG 1-A

Case 5 July 19, 1946 Early evidence of process is visible over right trochanter

Fig. 1-B

August 20, 1946. There is widespread evidence of early lesion. Shadows are soft but definite.

Fig. 1-C

December 28, 1946. Further advancement has occurred, medially and superiorly.

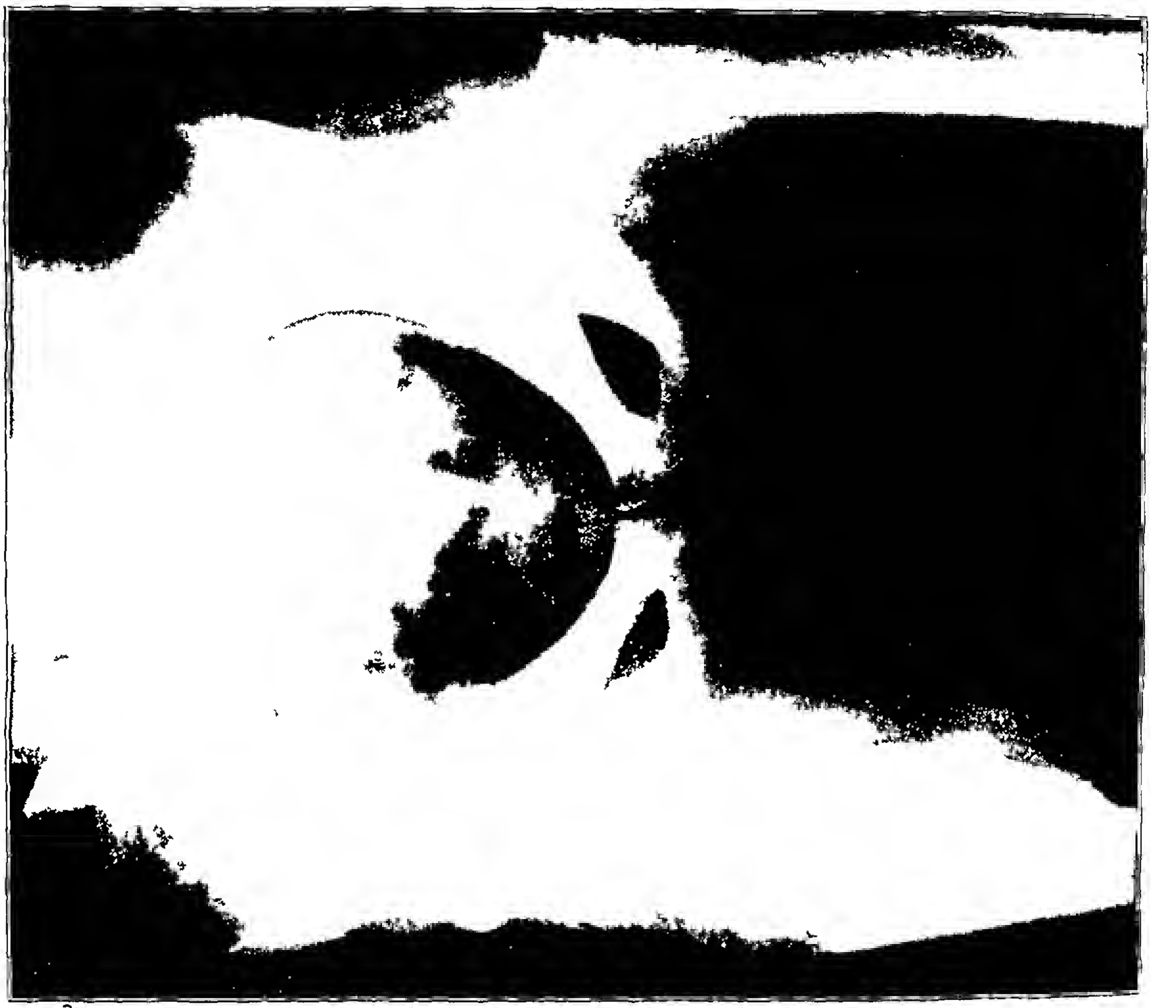

Fig 1-F

Fig 1-D

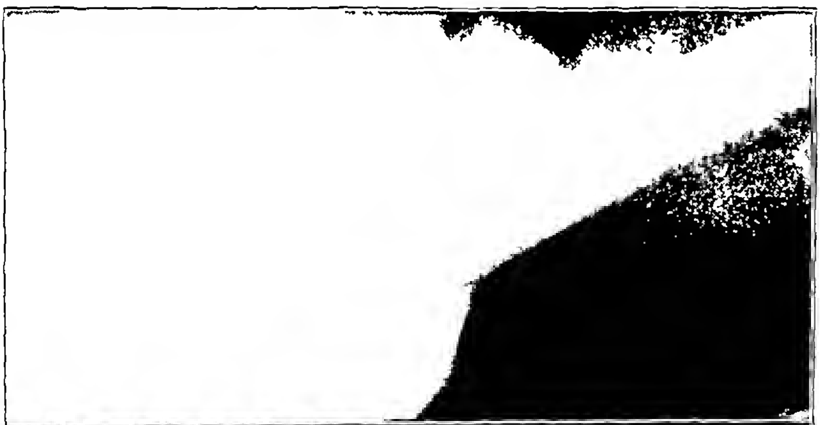

Fig 1-E

Figs 1-D and 1-E January 3, 1947 Anteroposterior and lateral roentgenograms show medial and anterior location of mass of new bone

Fig 1-F May 26, 1947 Consolidation of lesion has taken place

the liberty of quoting extensively from their findings, because of the scarcity of reported material

At the medial femoral condyle, Dejerine describes a compact bony nodule or prong, and, along the diaphysis, a fine latticework of spongy bone The spongy bone approximates the calcification at the medial condyle and along the femoral shaft by contiguity rather than continuity The hip joints present a bony scaffolding in three parts Anteriorly, a band extends from the anterior inferior iliac spine to a line between the trochanters, in front of the joint capsule and beneath the iliopsoas Posteriorly, the calcification extends from the ischium to the posterior border of the greater trochanter Inferiorly, a more slender bridge arises from the iliopubic region and attaches at the lesser trochanter The implantations about the femoral neck are compact bone, but the rest is spongy The bone grows from each side and joins over the neck The joints themselves are not involved, unless they are the site of purulent arthritis or osteo-arthritis In the soft tissues far from the skeleton, new-bone growth appears in muscle It begins as bony points or needles, disseminated under the fascial envelope of the muscle, in hyperplastic, dense connective tissue Bony plates, formed in one patient, were found to be 18 centimeters long and 2 centimeters wide These were irregular, jagged, and largely fenestrated The tissue was rather compact under the anterior thigh muscles, but had no skeletal attachment There was complete absence of infection or hemorrhage, nor was any new-bone formation seen in decubitus ulcers or scars

Histologically, Dejerine's description is in accord with the authors' findings Slender trabeculae, in cords or folds, limited the large medullary spaces There was abundant vascularity in the marrow, which was rich in fat cells and connective tissue, and islets of hemorrhage were present In the central portions between trabeculae, the marrow was made up of a fine, slightly vascular, reticular tissue, containing large fat cells, in the

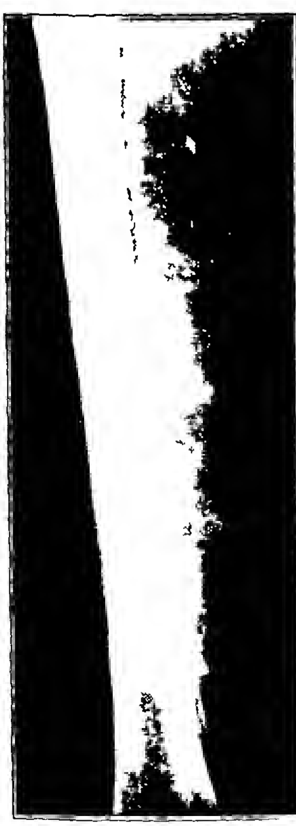

Fig 2-A

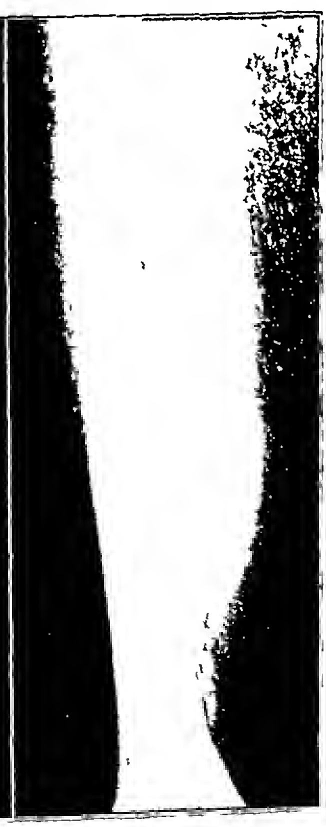

Fig 2-B

Fig 3-A

Figs 2-A and 2-B Case 2 June 3, 1946 Anteroposterior and oblique views of diaphyseal calcification
Fig 3-A Case 4 November 15, 1946 Knee involvement is evident

interstices of which were vividly colored myeloid cells Toward the periphery, where the trabeculae join, the connective-tissue stroma was dense, vascular, hemorrhagic, and continuous with the fibrous wall, similar to periosteum Lining this layer, next to the trabeculae, were cells like cylindrical epithelium, similar to osteoblasts The trabeculae showed a regular or irregular series of bone cells in uneven thickness of bony lamellae These were avascular, but had Haversian canals, around which bone cells were disposed in concentric lamellae In one case, plaques of cartilage were also present The cartilage cells were not grouped in orderly patterns and were varied in shape, some being globular and others elongated In some places these cells were immersed in a basophilic substance which tended toward a zone of acidophilic staining Other cells, however, stained poorly, were scarce, and were surrounded by a substance only slightly basophilic Outside of this was the osteoblastic layer Near centers of ossification, true intramuscular and perimuscular sclerosis occurred In one case, the cross striations of muscle were gone and there was a proliferation of the nuclei of the sarcolemma The fibers were atrophic and segmented, as in any lesion of the cord or roots The muscle fasicles were separated and appeared drowned in a connective-tissue oedema

The gross pathological findings in the authors' case were described by Dr Fred Hark at the time of surgery Both the right and left hips were operated upon, because the patient was unable to sit in a wheel chair In the right hip the calcification was found to involve the rectus femoris, from its origin to the junction of the proximal and distal half of the muscle The joint capsule was calcified, and the vastus lateralis also had some calcium deposits A lip of calcification extended from the anterior inferior iliac spine

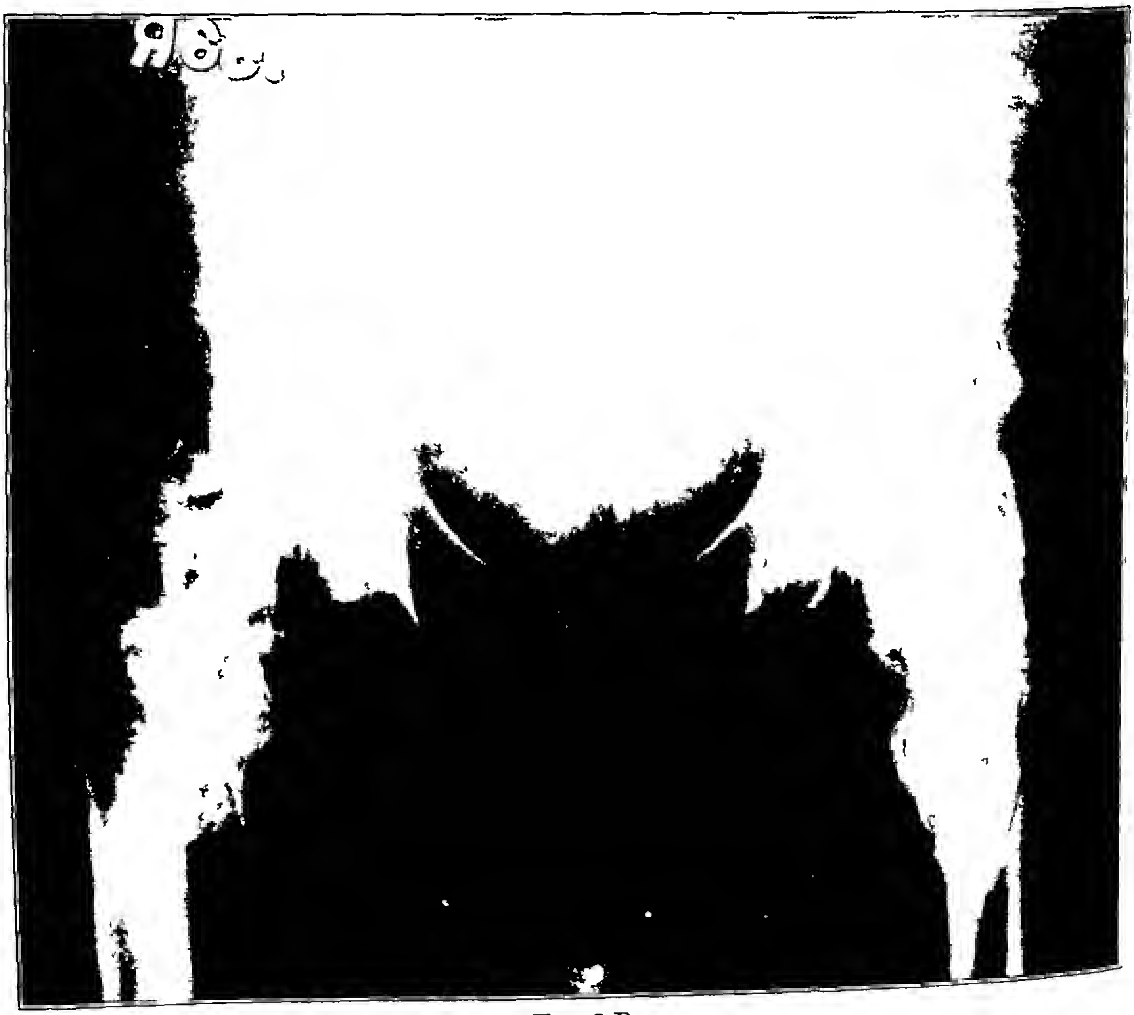

FIG 3-B

November 15, 1946 Preoperative film of lesions of both hips, limiting hip motion

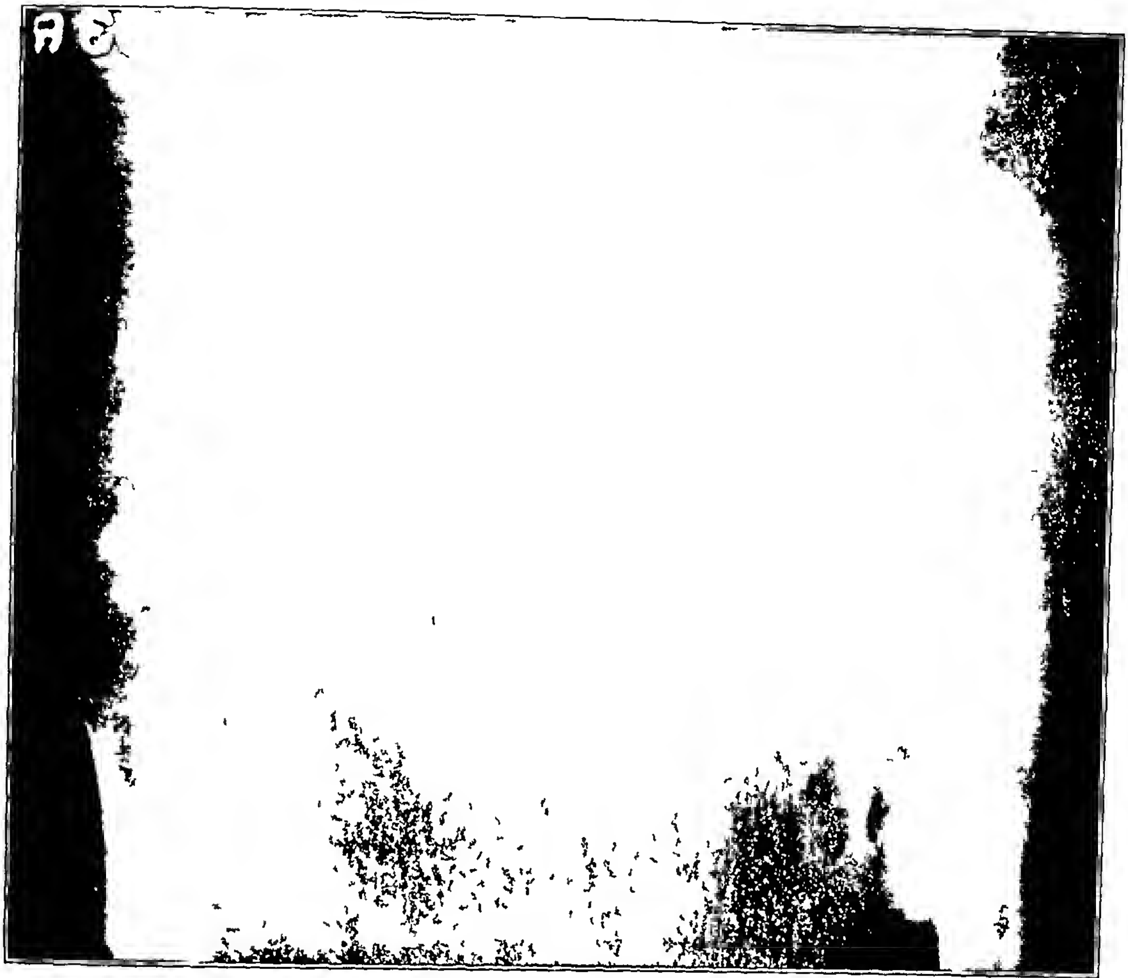

Fig. 3-C

February 5, 1947. Postoperative film after surgical procedures on both hips.

Fig. 3-D

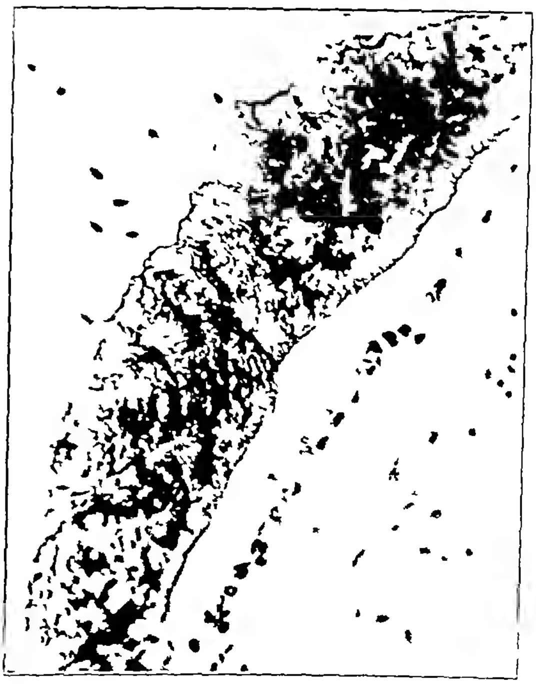

Fig. 3-E

Fig. 3-D. High-power view of fibrosis within the degenerated muscle tissue.

Fig. 3-E. Dark-staining cartilaginous tissue with border of osteoblasts laying down new bone. At the top is osteoid tissue.

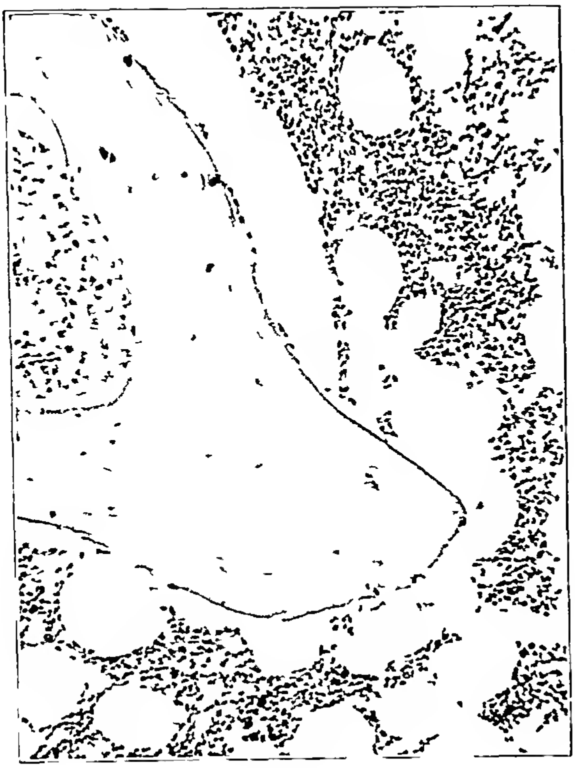

FIG. 3-F

FIG. 3-G

FIG. 3-H

Fig. 3-F. Low-power photomicrograph of bone trabeculae with surrounding marrow cells, as in adult bone.

Fig. 3-G. High-power view of adult bone and marrow cells.

Fig. 3-H. Lower portion shows atrophic muscle and fibrosis, with portion of adult bone at top.

downward and medially, blocking the front of the hip joint. The femoral head and acetabulum were normal. On the left hip, the rectus femoris was involved from its origin to the mid-thigh. Calcification was lobulated and covered by a connective-tissue sheet, from which adjoining tissues were easily stripped away. A few fibrous bands came from between the lobulations, particularly along the lateral aspect. Upon chiseling into this calcification, it was observed that there was a suggestion of a thin cortex and that the internal composition of the calcification was a fairly dense cancellous type of bone, which, for the most part, appeared white and lacked any amount of vascularity. In the lower portion, however, at least two vessels were severed, and one in the extreme upper pole of the wound caused a moderate amount of hemorrhage. The cancellous bone involved the anterior portion of the capsules of the hips. The head of the femur was soft and compressible upon direct pressure with the finger.

Histologically, two separate reports from different pathologists were obtained of the same slides and were practically identical. There was marked fibrosis and degeneration of the muscle with atrophy. The new-bone formation appeared entirely normal and con-

TABLE I

ANALYSIS OF CASES

Case No.	Levels of Lesion	Spasm	Genito-Urinary Calculi	Period Prone	Calcium (9 to 12 mg./100 c.c.)	Phosphorus (2.5 to 4.5 mg./100 c.c.)	Alkaline Phosphatase* (0.5 to 5.0 Bodansky Units)
1	Second lumbar	++	No	1 year	9.7	3.7	3.8
2	Fourth, fifth, and sixth thoracic	+	No		11.6	3.6	4.0
3	Third and fourth thoracic	+++	No	2 months	11.5	3.6	17.1 and 8.5
4	First lumbar	0	No		11.0	3.6	6.9
5	Sixth thoracic	+++	Yes	2 years	10.8	4.5	5.1
6	Fifth thoracic	++	No	3 months	10.8	3.5	2.8
7	First lumbar	0	Yes	Frequently since injury in 1935	10.9	3.5	6.3
8	Twelfth thoracic	+	Yes	2 months	11.2	4.4	10.2
9	Ninth thoracic	++	No	2 months	10.9	3.7	3.9
10	First lumbar	+	No	6 months	10.4	3.4	5.9

* Alkaline-phosphatase values, as determined in our laboratory, are felt to be of little significance until elevated above 10 units. Case 3 shows a high value which was rechecked and found to be nearly normal. This patient was physically inactive, and showed a marked increase in his osteoporosis and progressive stiffness of the joints of the lower extremities. Case 8 shows a high value, possibly because there was some evidence of extension of the original myositis ossificans.

tained normal marrow blood-forming cells. The bone trabeculae were of the adult type. One area showed the deposition of calcium salts within and around young cartilage cells and osteoid tissue. Except for this one area, no active osteoblastic proliferation was seen. Throughout the slides there were dense collagenous deposits with few cells, and in the areolar tissue and fat were numerous blood vessels (Figs. 3-D to 3-H, inclusive).

Theories of Formation

Many theories exist for the development of myositis ossificans. Each can be applied to a particular case and would adequately explain why new bone is formed, but no one theory explains why osteogenesis occurs instead of fibrosis. The particular elements present which make the situation favorable for bone formation are discussed by various writers.

Dejerine and her associates attach considerable importance to the subcutaneous and deep oedema of the tissues, which modifies or alters in some way the resistance of the connective tissue, and to the functional irritability of the nerve elements of the intermediate lateral sympathetic column of the spinal cord, immediately adjacent to the traumatic lesion. They feel that detachment of the periosteum could explain ossification around the epiphyseal and diaphyseal portions of the bone, but that it does not explain the intramuscular ossification. They believe that a metaplasia occurs.

This group of workers further contend that all primitive connective tissue is capable

of forming fibrous tissue, tendon, muscle, cartilage, or bone, since all have a common origin from mesoblastic tissue Perhaps by cord trophism, under the indirect influence of oedema and of functional irritation from the intermediate lateral sympathetic column and under the direct influence of necessary handling of patients, which produces traction on connective tissue, ligaments, muscles, and tendons, metaplastic phenomena are produced, causing para-osteo-arthropathies in these paraplegic patients

Stanger recently suggested two possible causes for osteogenesis in transverse cord lesions The first is "impaired urinary excretion of nitrogenous bodies, causing a mobilization of calcium from the bones of the paralytic limbs" Second, a Charcot-like reaction occurs around a denervated joint, subjected to passive stretching

In transverse cord lesions, Geldmacher's theory from the study of his cases was analogous to that of Leriche Geldmacher believed that the tissue loses its character by trophic influences and assumes the character of embryonic tissue Calcium salts are mobilized from the atrophic bone which accompanies the paralysis, making the situation favorable for bone formation Frejka gives Leriche's theory of the conditions necessary for bone formation (1) embryonic connective tissue, stimulated by hemorrhage, rheumatic or purulent inflammation, trophic changes from cord lesions, et cetera, and (2) local increase in lime salts in lymph, produced by absorption of adjacent bone He thinks that the local ossification differs from the progressive form in that a general predisposing dystrophy or diathesis is lacking, but that all types of myositis ossificans should be considered as the same malady

NOTE This paper is published with the permission of the Chief Medical Director, Department of Medicine and Surgery, Veterans Administration, who assumes no responsibility for the opinions expressed or the conclusions drawn by the authors

The patients studied were cared for on the Paraplegic Service, which is under the supervision of the Department of Nervous and Mental Diseases of Northwestern University Medical School, through the auspices of the Deans' Committee of the Veterans Administration Hospital, Hines, Illinois

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KÜNTSCHER'S MEDULLARY NAILING

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From the Unfallkrankenhaus, Wien

At the sixty-fourth meeting of the *Deutsche Gesellschaft für Chirurgie*, held at Easter time, 1940, Küntscher presented his new method for the treatment of fractures of the shafts of the long bones. His method, which is employed after exact reduction of the fragments, consists in the insertion of the so-called "medullary nail", a long stainless-steel pin, through a small incision at a point away from the fracture site. This medullary nail unites the fragments so firmly that, as a rule, the fractured limb can be lifted at once and can be moved actively without additional external support, like the nailed fracture of the neck of the femur. After bony union, the medullary nail can easily be removed by a simple operation.

Closed medullary nailing has two great advantages over former types of osteosynthesis,—namely (1) almost complete avoidance of infection, and (2) complete stability, so that, as a rule, no other supports have to be used.

In fractures of the femur, the fragments can slide along the nail and be pressed together. The medullary nail eliminates all detrimental factors of traction and shearing, and only the favorable factor of pressure exists. The callus formation is thereby enhanced, while it is often hindered by the use of plates, as the fragments are held apart (Figs. 8-A and 8-B). Furthermore, with closed medullary nailing, the hematoma and fracture detritus so important for the regeneration of bone are retained, and the periosteum and adjoining tissues are not further traumatized. The three main rules of fracture treatment—reduction, fixation, and exercise—are accomplished in an ideal manner.

Therefore, in properly selected fractures of the shaft of the femur, closed medullary nailing is far superior to all known forms of treatment. This method has also proved worth while in the treatment of localized osteitis fibrosa cystica of the femur and the humerus (Figs. 5-A, 5-B, and 5-C).

Küntscher recommended his method for fractures of all long bones. The authors have used medullary nailing since 1940 in about 700 cases. Except in fractures of the femur, we now use it only occasionally in closed transverse fractures of the humerus; we no longer use it for fractures of the tibia or of the forearm.

Some time ago, feeling that our results were unsatisfactory in fractures other than those in the femur, we reviewed all of our cases. The review indicated that, in bones other than the femur, the results were better by conservative methods than with nailing. In many cases, fixation of the tibia by the nail is not mechanically firm enough to eliminate the need for external fixation by plaster. As a result of the curved path of the nail in the tibia, the metal must of necessity be bent and may hinder approximation of the fragments by diastasis of the bone ends, leading to delayed union or even to non-union. Because of these complications and because healing may be greatly delayed through minor technical errors, the authors have completely abandoned the use of the intramedullary nail in the tibia. These findings were emphasized even more strongly in ununited fractures and in compound fractures of the tibia.

The use of the nail has also been discontinued in forearm fractures, for the same reasons. In fracture of a single bone of the forearm, coaptation can be maintained by simpler means. If intramedullary fixation is used in fractures of both bones, it is necessary to fix both bones. In the radius, as in the tibia, the bent nail is undesirable.

The theoretical objections raised against medullary nailing have been refuted by practical experience. In adults, the amount of destruction of the bone marrow by the

medullary nail is of little significance The medullary nail is a large foreign body It will not, however, cause significant reaction if a completely inert stainless steel is used, little effects are noted only with stainless steel which is not completely inert The medullary nail hinders callus formation, as does every foreign body, and is not, as Kuntscher thought conducive to callus formation An increased formation of callus appears only if the medullary *nail does not fix the fragments sufficiently or if an oxidizing* metal is used By the mechanical or electrochemical activity an irritation callus arises, and for a long time the limb cannot be trusted to bear weight

The insertion of the medullary nail does not cause a clinically evident fat embolism, because by its construction the nail permits the marrow to flow through it, and, therefore, does not act like a piston When a solid steel rod is used instead, fat embolism may occur Infections are infrequent with medullary nailing, however, if an infection should arise, the whole marrow cavity along the nail might become infected We have in our own cases not seen any serious progressive infection as a result of closed medullary nailing Kienslehner reported acute and fatal osteomyelitis in an adolescent Therefore, we do not nail fractures in bones in which the epiphyses have not yet closed

Although the danger of medullary nailing seems to be small, the authors, while examining about 700 cases in different hospitals, have seen a great many complications, due to faulty indications, improper technique, improper instruments, or faulty material The most serious, and even fatal, incidents occurred because the operation was performed while the patient was in shock

Exact indications are necessary The most suitable fractures are transverse and short oblique fractures at the middle third of the femur, they should be at least seven centimeters from the tip of the trochanter or from the knee joint The patient must be in good general condition The skin must be intact and show no inflammation or burns Other foci, a possible cause of metastatic infection of the fracture, should be ruled out Absolutely no shock should be present This danger is especially great if the nail used is too wide, since force is necessary to drive it in and death may occur

The proper instruments must be available, including nails of the proper length and width and sufficient instruments for a bone operation A special reduction apparatus is necessary for closed nailing The authors use either their screw-traction apparatus (Fig 1) or Wittmoser's reduction apparatus (Fig 2) Two portable x-ray machines are needed to afford biplane roentgenographic control without changing the position of the machine

The operation is performed with repeated roentgenographic checks, so that care must be taken to prevent x-ray burns In order to protect the patient, the x-ray tubes must be kept at least thirty centimeters from the skin The fluoroscope operator should be allowed to work only when protected with lead apron and lead gloves A reduction apparatus must be used, which reduces the fragments and maintains position mechanically Inattention to these details may result in severe x-ray burns, as happened so often to older roentgenologists or orthopaedic surgeons

Closed Medullary Nailing of the Femur

Closed fractures are best nailed within the first hours of injury If shock is present, it is well to wait from eight to ten days, until the acute reaction has subsided In the meantime, skeletal traction is applied

After the width and the length of the bone have been determined by means of good roentgenograms, and after proper medullary nails have been selected, spinal anaesthesia is given The patient is placed on a reduction apparatus (Figs 1 and 2) With fractures of the lower third of the femur the knee should not be extended, but semiflexed (Fig 2) One x-ray machine is placed at the ventral aspect and a second one at the medial side of the thigh By means of longitudinal traction, the shortening will be overcome, and by means of canvas slings or wooden rings, attached to rotating bars, the lateral displacement is cor-

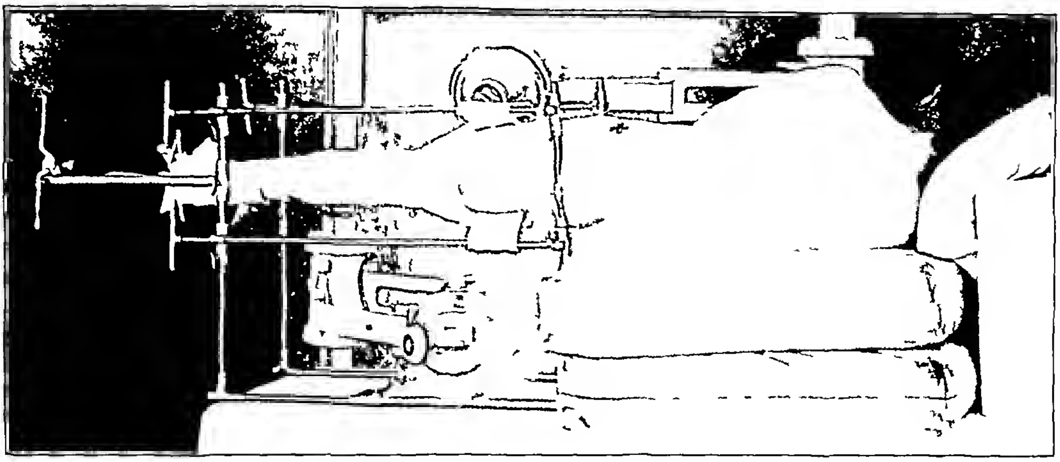

FIG 1

The femur is fixed for medullary nailing in the Bohler screw-traction apparatus The patient lies on the well side, bent slightly forward so that the greater trochanter is better exposed The uninvolved extremity is acutely flexed at the hip The point of insertion of the medullary nail is marked with a cross The fragments are reduced and fixed firmly in correct position by means of rotating double bars and canvas slings Two x-ray tubes are placed in position for fluoroscopy and roentgenography (Reproduced, by permission of The Williams and Wilkins Company, from *Medullary Nailing of Küntscher*, by Lorenz Bohler)

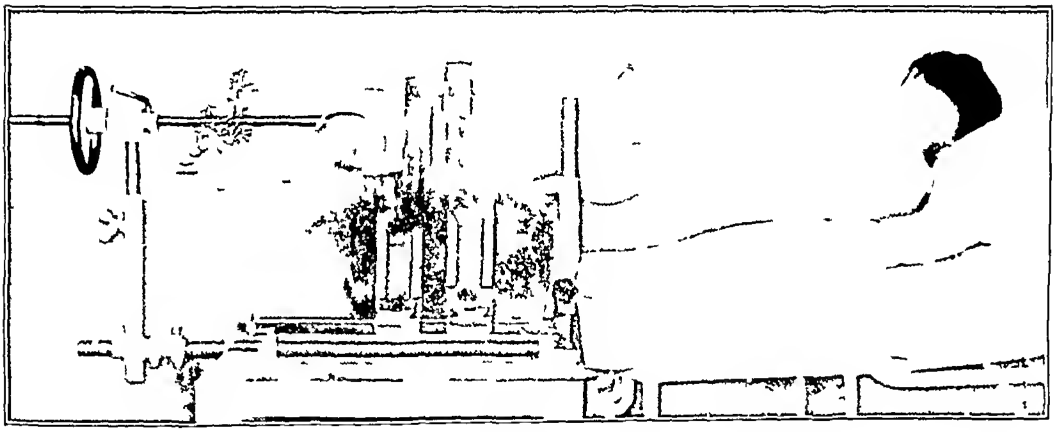

FIG 2

Fracture of the femur, with patient placed in Wittmoser's reduction apparatus In fractures close to the knee joint, the knee is flexed to a right angle

rected If fluoroscopic control shows good reduction from each side, roentgenograms are taken If they show good alignment of the fragments, the area of the hip is prepared in a sterile manner

An incision of about two to three centimeters in length is made, five centimeters above the tip of the trochanter An awl is inserted, to the medial side of the greater trochanter, into the marrow cavity The nail guide is then inserted, by means of a handle through this hole, its course being checked by fluoroscope As the guide advances toward the knee joint, additional roentgenograms are taken When they reveal a satisfactory position, the medullary nail is driven over the nail guide with a hammer, again under fluoroscopic control As the medullary nail approaches the skin the nail guide is withdrawn and the nail is hammered farther in with a nail-driver, until it extends only two centimeters from the tip of the trochanter and one centimeter from the knee joint The wound is then closed and again roentgenograms are taken Should diastasis exist at the fracture site, it is overcome by a strong thrust with the flat of the hand against the knee joint

Reduction may be very difficult and should never be tried without a reduction apparatus The insertion of the nail guide may also be troublesome but usually no difficulties arise in driving in a nail of the proper width

After the operation, the lower extremity is placed on a Braun frame, and the toes and ankle joint are moved actively from the first day The hip and knee joint should not be

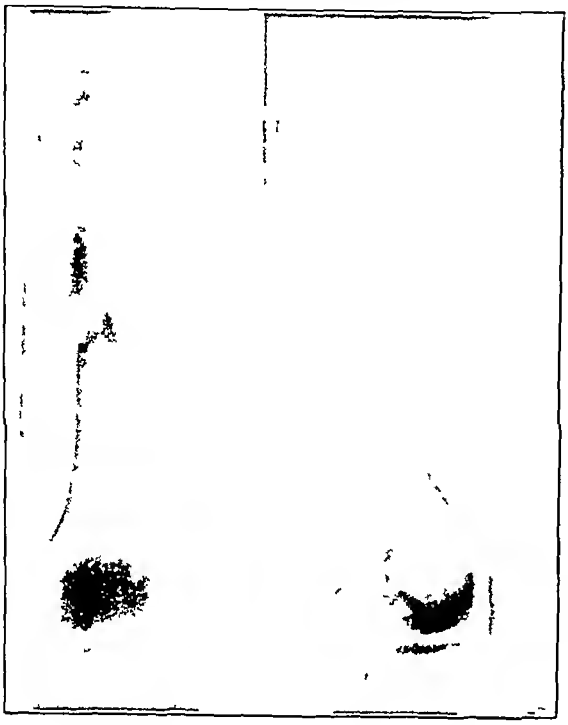

FIG 3-A FIG 3-B FIG 3-C FIG 3-D

Figs 3-A and 3-B September 16, 1947 Compound fracture of the right femur between the middle and lower thirds

Figs 3-C and 3-D September 16, 1947 Closed transverse fracture of the shaft of the left femur Skeletal traction was applied through the tuberosity of the tibia

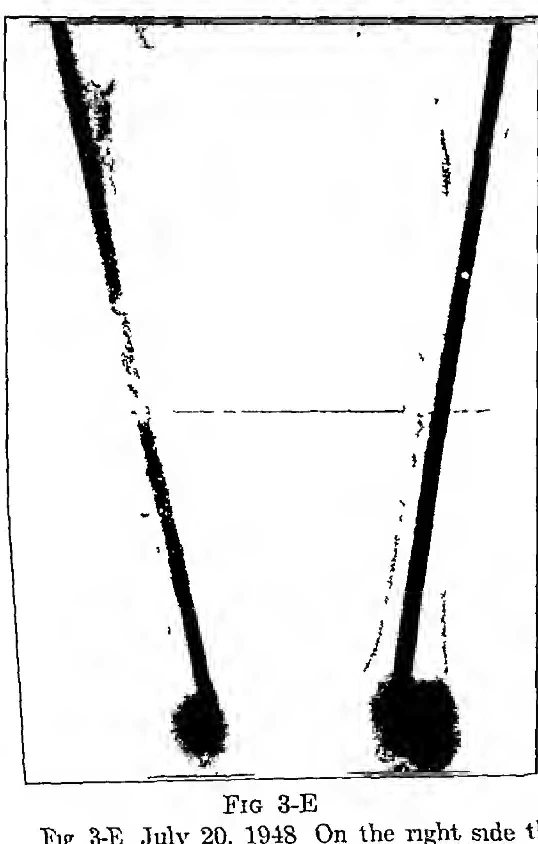

FIG 3-E FIG 3-F

Fig 3-E July 20, 1948 On the right side the wound was excised immediately, a medullary nail was inserted, and three encircling wires were applied Healing occurred without wound complications Closed medullary nailing was accomplished on the left side, sixteen days after the accident Solid bony union and good position resulted on both sides

Fig 3-F July 29, 1948 After removal of the nails, ten months after the accident

moved until eight days after operation If the nail is in good position and no other injuries exist, the patient may start weight-bearing after eight to ten days, and he may leave the hospital after two or three weeks

Closed Medullary Nailing in Localized Osteitis Fibrosa Cystica

The cyst is located usually in the upper third of the femur or the humerus, seldom in other bones It is a typical disease of pressure By pressure the bone is resorbed until finally only a paper-thin cortex remains, because there is no simultaneous periosteal apposition (Fig 5-A) An insignificant force finally causes a pathological fracture Thus the wall of the cyst is opened and the pressure is released New-bone apposition occurs and, as a rule, the fragments unite Sometimes the cyst heals completely, but generally a new one is formed, because the wall of the cyst is closed by callus formation and new pressure arises

The ailment can be healed by opening and curettage or, better, by filling the defect with bone grafts or bone chips In the case illustrated here (Figs 5-A, 5-B, and 5-C) the authors inserted a medullary nail By this procedure alone, without curettage or bone-grafting, the condition healed completely

A woman, aged twenty-eight, of good general condition, fractured the right humerus in May 1946 Prior to this she had occasionally had pain in the right shoulder The roentgenograms showed a cyst in the right humerus, with a fissure The fracture healed

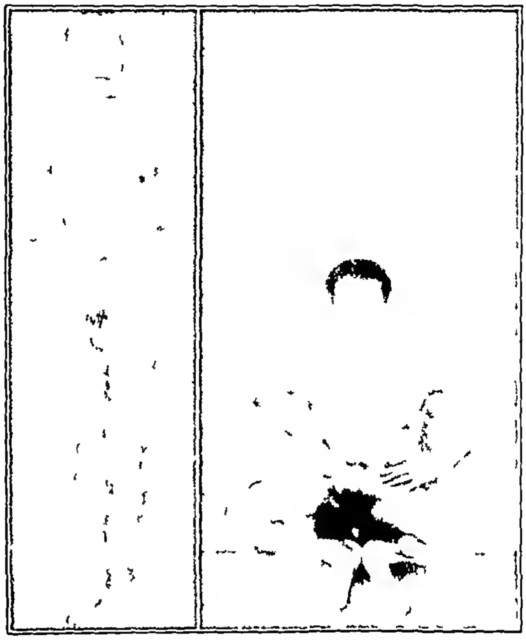

FIG 3-G FIG 3-H

February 12, 1948 Function five months after the accident Patient had started walking four weeks after the accident, and six weeks later could bend both knees to 90 degrees

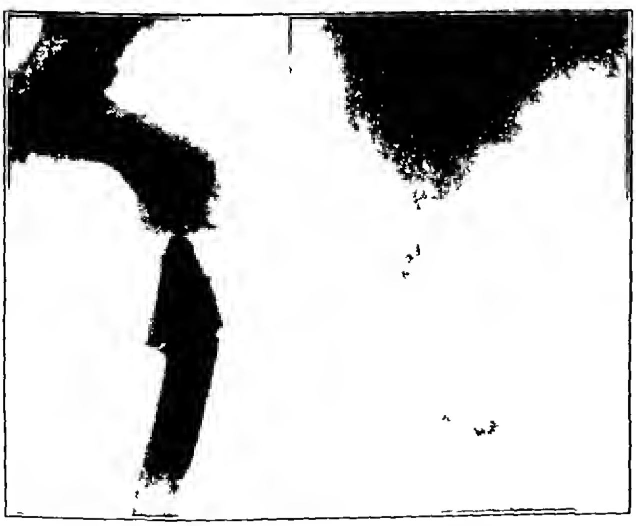

FIG 4-A FIG 4-B

FIG 4-C FIG 4-D

Figs 4-A and 4-B July 7, 1948 A policeman, thirty-four years old, sustained a compound, comminuted fracture of the left femur in a street accident, with wounds on the anterior and posterior aspects of the thigh Marked posterior displacement of the distal fragment can be seen

Figs 4-C and 4-D August 9, 1948 Five weeks after the accident After thorough excision of t wound, open medullary nailing was performed and four encircling wires were applied Healing t place without wound complications Weight-bearing not yet a

Fig 5-A Fig 5-B Fig 5-C

Fig 5-A January 14, 1947 A librarian, twenty-eight years old, had a solitary cyst in the head of the right humerus, about 3 5 by 5 centimeters in size The cortex was only 0 5 millimeter thick laterally

Fig 5-B July 14, 1947 Six months after medullary nailing, the area of the cyst had nearly filled in with newly formed bone tissue The medullary nail remained in place

Fig 5-C June 23, 1948 Seventeen months after medullary nailing and immediately after removal of the nail, the former cyst had completely filled with new-bone tissue No discomfort remained

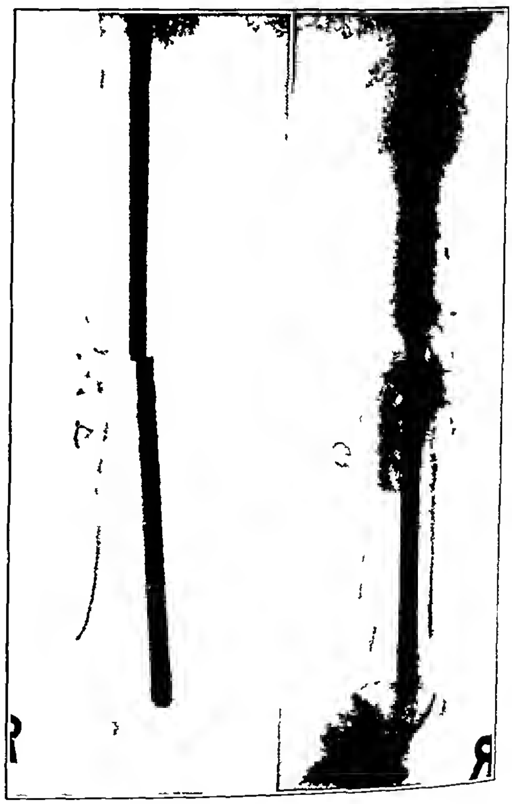

Fig 6-A Fig 6-B Fig 6-C Fig 6-D

Figs 6-A and 6-B January 10, 1946 Pseudarthrosis of the right femur in a student, twenty-three year old, due to gunshot fracture, three years before Numerous shell fragments remained Sclerosis was present at the fracture site

Figs 6-C and 6-D June 1, 1947 Seventeen months after open medullary nailing, the nail, which was short, had become loose As a result there was no bony union and the nail had broken After correction of angulation, the medullary nail was removed through a small incision in the trochanteric area and was replaced by a longer one The knee joint was later mobilized by open operation

FIG 6-E FIG 6-F

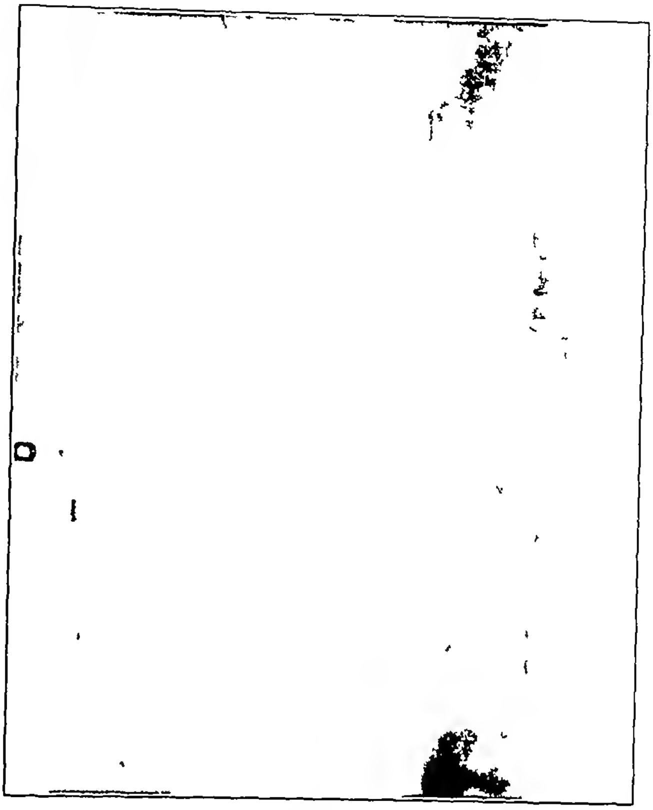

FIG 6-G

Figs 6-E and 6-F July 17, 1946 The left femur was shortened eight centimeters, and a medullary nail and a wire loop were inserted

Fig 6-G March 9, 1948 After removal of the medullary nails, both femora had healed in good position and were the same length

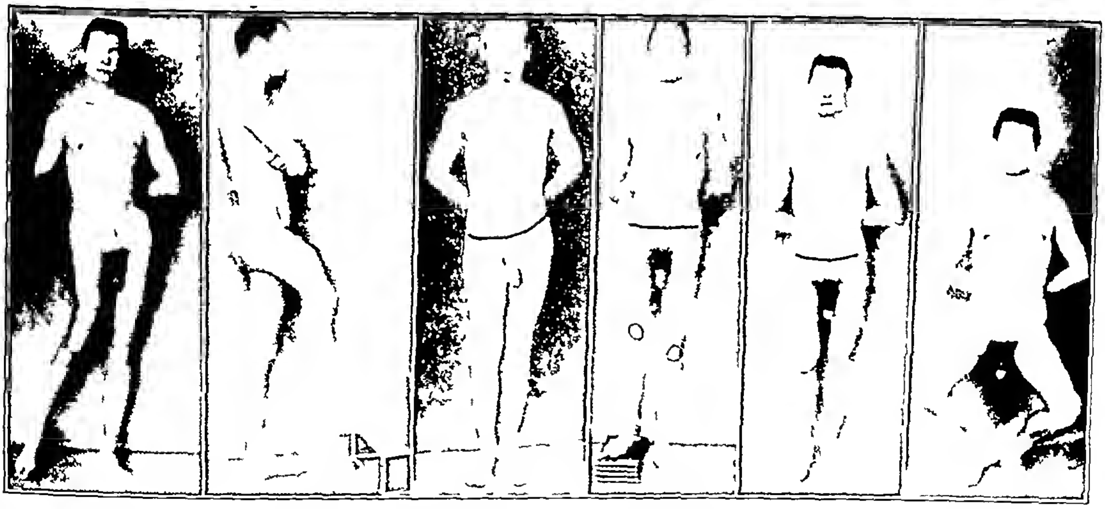

FIG 6-H FIG 6-I FIG 6-J FIG 6-K FIG 6-L FIG 6-M

Figs 6-H and 6-I January 19, 1946 Photographs before treatment show abnormal mobility and shortening of nine centimeters Knee-joint range from 170 to 160 degrees

Figs 6-J and 6-K June 16, 1946 After medullary nailing of the pseudarthrosis, shortening of the right lower extremity was still present

Fig 6-L March 9, 1948 After shortening of the left femur, both extremities were the same length

Fig 6-M March 9, 1948 After open mobilization of the knee joint, knee flexion was possible to 90 degrees

without incident In July 1946, the patient came to our Hospital In January 1947, a medullary nail was driven into the cyst and the arm was immobilized for ten days Soon afterward the shoulder joint was free and the pain had disappeared The cyst was almost completely filled with new-bone tissue, remnants of the

FIG 7-A FIG 7-B FIG 7-C FIG 7-D FIG 7-E FIG 7-F

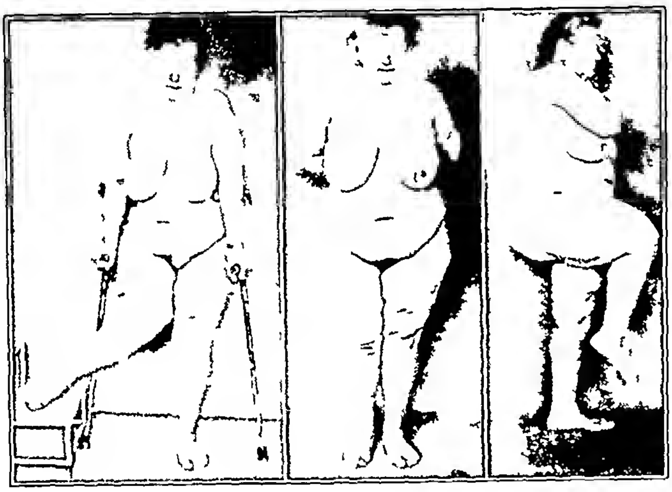

FIG 7-G FIG 7-H FIG 7-I

Figs 7-A and 7-B January 10, 1946 Pseudarthrosis of the right femur of two years' duration, following infected compound fracture after a motorcycle accident in a landlady, fifty-one years old Height 165 centimeters (65 inches), weight 90 kilograms (198 pounds) Shortening of five centimeters and marked atrophy of the bones were present

Figs 7-C and 7-D January 26, 1946 The shortening was corrected after fourteen days of skeletal traction, and open medullary nailing was performed Ideal position seen from both sides The fragments were held by a wire loop against rotation, and one rubber drain was left The patient walked without external fixation three weeks after operation

Figs 7-E and 7-F March 17, 1948 After removal of the medullary nail, bony union was present with the fragments in ideal position The patient fractured the patella in a fall

Fig 7-G January 11, 1946 Photograph before treatment shows abnormal mobility at the fracture site

Figs 7-H and 7-I March 17, 1948 Two years after operation patient had good use of extremity and was able to walk without a cane Range of knee motion from 160 to 90 degrees

cyst are still to be seen (Fig 5-B) One and one-half years after the operation the nail was withdrawn (Fig 5-C) The apposition of bone inside the cyst had taken place without incident, because the pressure was released, as the nail drained the cyst constantly

Unlike curettage and bone-grafting of the area containing the cyst, medullary nailing is a simple procedure and not dangerous No further fixation is necessary, because the medullary nail gives sufficient support The authors have operated upon three solitary cysts of the femur in the manner described here, with the same good results

Medullary nailing can also be used in spontaneous fractures occurring at the site of metastases of malignant tumors, which are found mostly in the upper third of the femur The patients can walk on the extremity with the nail, although the fracture fragments will not reunite

Open Medullary Nailing of the Femur in Compound Fractures (Figs 3-A through 4-D)

With open medullary nailing the fragments must be freed, as in any other form of osteosynthesis The great advantage of closed medullary nailing, the small danger of in-

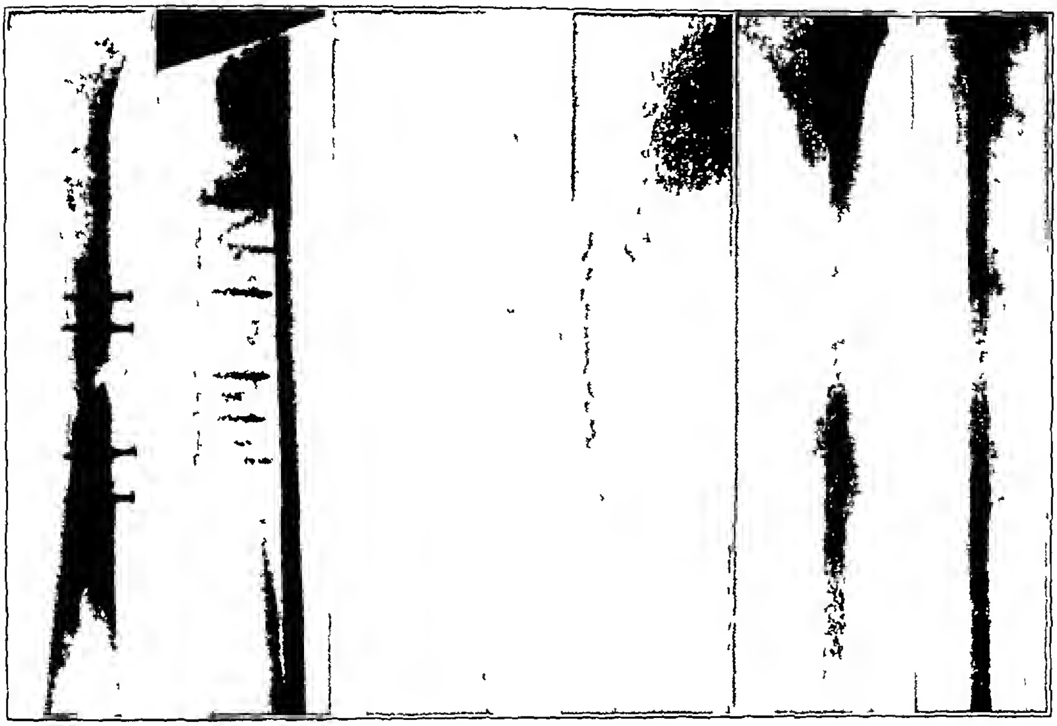

FIG 8-A FIG 8-B FIG 8-C FIG 8-D FIG 8-E FIG 8-F

A postman, thirty-two years old, fractured his left femur a year and a half prior to admission Wire traction was applied for seven months with ten to twenty kilograms of weight (twenty-two to forty-four pounds) A pseudarthrosis resulted and osteosynthesis was done with bone graft and plate (Observation of Dr Neubauer, Graben Hospital, Graz)

Figs 8-A and 8-B May 3, 1946 Very good position resulted after operation with bone graft and plate for pseudarthrosis of left femur Diastasis was present at the fracture site

Figs 8-C and 8-D December 7, 1946 In spite of three months' fixation in a hip spica, no bony union resulted The bone graft broke and angulation of fragments occurred Varus and anterior angulation are shown, each of 30 degrees

Figs 8-E and 8-F Bone graft and plate were removed and one month later medullary nailing was performed Thirteen months later (on August 5, 1948), the patient could walk several hours without a cane and was doing full duty as postman The medullary nail was still in place and he had no complaints

fection, does not apply, but the other advantages—namely, stable union of the fragments and free mobility of the limb—still exist

The indications for open medullary nailing must be given exactly The authors never use this form of treatment in infected and draining fractures They use it in all recent compound fractures of the shaft of the femur without joint involvement, and in those patients whose general condition permits

Open medullary nailing is much easier to perform than closed After exact debridement of the wound, with the patient under local anaesthesia, the nail guide is inserted into the central fragment from the fracture site and is advanced through the tip of the trochanter to the skin A skin incision, two or three centimeters in length, is made at the point where the guide appears under the skin, and a short medullary nail is driven from above, over the nail guide, one centimeter into the trochanter The nail guide is pulled out and a new one is inserted from above, through the medullary nail, into the central fragment, until it appears at the fracture site Then both fragments are approximated and held by means of bone forceps, and the nail guide is inserted into the distal fragment until it reaches the region of the knee joint If the position of the fragments and of the nail guide is satisfactory, as ascertained by two check roentgenograms a medullary nail of the proper length and width is driven in and the fragments are impacted by thrusts on the knee with the flat of the hand Rotation is controlled by means of a longitudinal wire loop (Figs 6-G and 7-C to 7-F) In oblique and spiral fractures an encircling wire is applied After insertion of a rubber drain, the skin is closed

The leg is placed on a Braun frame, as is done after closed medullary nailing. The drain is removed after twenty-four hours. The toes and ankle joint are moved, beginning on the first day. Motion of the knee joint is started three weeks later. If the wound heals without incident, the patient may get up during the fourth week.

To date the authors have nailed about thirty fresh open fractures of the femur. In only one case did a slight infection develop. Five months later a small sequestra was removed and the existing fistula was closed.

Open Medullary Nailing in Cases of Malunion or Non-Union of the Femur (Figs. 6-A to 8-F)

When a fracture of the femur has united with shortening of more than three centimeters and with angulation or rotation of more than 15 degrees, the patient limps. Later, osteo-arthritic disturbances develop in the hip and the knee joint, and occasionally even in the ankle joint of the injured limb, and, in marked shortening, also in the sound limb and in the spine. Non-union of the shaft of the femur cripples the patient severely and should be corrected. Especially in these cases with malunion or non-union, medullary nailing represents great advance, because no external support is necessary and the atrophic muscles and joints with limited motion do not need to be immobilized further.

Contra-indications for the operation are found (1) in an unfavorable general condition, (2) in osteotomies in patients over fifty, (3) in non-unions in patients over sixty, (4) in patients under sixteen, because of the danger of acute osteomyelitis, (5) in infections of the bone and the skin, and (6) with enlarged ossifications of the marrow cavity due to old callus formation. Fistulae should have been closed for six months to one year. All scars, especially when adherent to the bone, should have been excised previously. Medullary nailing should be performed only after the new scar has become firm and is easily movable on the base, usually this takes about two or three months.

If shortening of more than three centimeters is present, it is very difficult to reduce this during operation, because the muscles are contracted. If an attempt is made to equalize greater shortenings by medullary nailing, severe vessel and nerve disturbances may occur as the result of the sudden tension, and wound infection may arise in the torn tissue. Therefore, the shortening must be corrected prior to medullary nailing. If the callus is not yet solid, the osteoclast may be used. If the callus is solid, the bone is cut with the chisel or the electric saw,—if possible, in the old fracture site. With non-union, the solid connections of the fragments are loosened by bending them over a wedge or with the osteoclast. If the inflammation of infected fractures does not flare up, it probably will not recur after the medullary nailing. Skeletal traction with adequate weight is next applied. After length has been restored, the medullary nailing can be performed. In the case of a closed osteoclasis, this is generally after one week, in the case of an osteotomy, about three to four weeks should pass.

The medullary nailing is performed with the patient in the lateral position, a sterile tourniquet being used. After the fragments have been freed, a longitudinal mark, five to six centimeters long and one to two millimeters deep, is cut into the bone with a small gouge, so that the amount of rotation can be determined. With angulation a corresponding wedge must be sawed, so that the fragments will touch each other exactly. The closed marrow cavity is opened with the awl or the gouge. In more recent cases, the authors have always bridged the fracture site with a piece of removed callus, a bone graft, or chips. The operation continues as for an open fracture, precautions against shock being observed.

Shortening of the Uninvolved Extremity by Medullary Nailing

If an unusual amount of shortening is present and the bone is not suitable for lengthening, only the angulation of the injured limb is corrected. After the patient has completely recovered from the first operation, the sound femur is shortened to equal the length

of the broken femur. This should not exceed eight or nine centimeters, because of the difficulty in accommodation of the muscles (Figs. 6-A to 6-M).

After application of a sterile tourniquet the sound femur is exposed above the middle third. A longitudinal marker, adequate to indicate rotation of the fragments, is chiseled out. Then the bone is sawed through transversely at the edge of the upper and middle thirds, a Gigli saw being used. The distal fragment is elevated and the correct length of bone is removed. Both saw cuts are thus in the narrow portion of the marrow cavity. To avoid rotation, step-cutting may be used, but transverse cutting is easier. Of late the authors have cut from the resected bone one or two strong grafts to bridge the site of the osteotomy. The operation then is continued as for an open fracture.

SUMMARY

At present, medullary nailing by the method of Kuntscher is the best treatment for transverse closed fractures, for open fractures, and for most of the osteotomies and nonunions of the shaft of the femur, if suitable equipment is available. The union of the fragments is so firm that the patient can walk without additional fixation after the wound has healed,—that is, in two or three weeks. Thus muscle atrophy and stiffness can be almost entirely prevented. With closed medullary nailing, the danger of infection is slight, because only a small incision is made apart from the fracture site. With open medullary nailing, the danger of infection is reduced by exact immobilization.

The authors also use medullary nailing for closed transverse fractures in the middle third of the shaft of the humerus. They no longer employ this method for fractures of the tibia or the forearm, as conservative methods have proved to be better.

Medullary nailing is a technically difficult procedure and should, therefore, be done only in specially equipped hospitals.

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SPONTANEOUS SACRO-ILIAC OBLITERATION IN PATIENTS WITH TUBERCULOSIS

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It is now recognized that the poor prognosis previously ascribed to tuberculosis of the sacro-iliac joint was the result of the associated widespread dissemination of the tubercle bacillus, rather than to the local disease process. Little has been written regarding the natural history and termination of the disease process in the joint under modern conservative management. The consensus in this country is that, in order to obtain bony ankylosis of this joint, operative intervention is necessary. The authors have recently observed, as an incidental finding in several patients coming to the Clinic for treatment of tuberculosis of the spine or hip joint, that one of the sacro-iliac joints has been obliterated by bony trabeculations. If these lesions represent the end result in patients with sacro-iliac tuberculosis who have not been operated upon, they lead one to question the advisability of bone-graft procedures for osseous fixation of the joint.

FIG. 1

A. K., January 16, 1945. Complete obliteration of the left sacro-iliac joint, represented by sclerotic changes. (Right joint entirely normal on detail films.)

EXPERIMENTAL DATA

Because the first sacro-iliac lesions recognized (Fig. 1) were incidental findings in patients with tuberculosis elsewhere in the body, it was felt that the best means of locating such lesions would be by reviewing all of the roentgenograms of the spine of patients at the Michigan State Sanatorium (for tuberculosis). Accordingly, the films of approximately 330 patients, representing the roentgenographic examinations of the back in approximately 6,600 patients admitted from 1930 to 1947, were reviewed. Twenty-two patients were

found with destructive and obliterative lesions, either alone or in combination, of *one* sacro-iliac joint To this group was added one patient who has been under observation at the University Hospital, but who was not cared for at the state institution

Fifteen of the patients were males and eight were females Their ages ranged from eight to sixty-two years with twenty falling in the three decades from eleven to forty The average age was twenty-eight years Nineteen of the patients were white, one was a Mexican one a negro, and two were Indian

These patients were under observation for periods varying from one month to thirteen years The average duration of observation for patients, either at the Sanatorium or in the Out-Patient Department of the University Hospital, was approximately thirty-eight months

FINDINGS

Seventeen (74 per cent) eventually had partial or complete obliteration of one sacro-iliac joint by bony ankylosis In fifteen of these patients, bacteriological proof of tuberculosis elsewhere in the body was obtained

Nine (39 per cent) of the seventeen patients, in their initial roentgenograms, presented partial or complete osseous ankylosis of a sacro-iliac joint (Fig 2) One had a draining tuberculous gluteal abscess on the side of the sacro-iliac involvement, which was interpreted by the examining physician as having arisen from concomitant lumbosacral Pott's disease This patient and two others had roentgenographic evidence of quiescent destructive lesions at other locations in the joint, associated with the osseous ankylosis Six patients showed evidence of obliteration without associated destruction

In the remaining eight patients with eventual fusion of one sacro-iliac joint, progressive destructive changes, with eventual healing while the patient was under hospital observation, were demonstrated on serial roentgenograms Of this group, three underwent operative fusion, and in two the tubercle bacillus was proved pathologically to be the etiological agent The third patient was an Indian who had a healed primary pulmonary tuberculous lesion, a strongly positive tuberculin reaction (1 to 10,000), and a history of recent tuberculous contact The pathological material obtained at operation failed to reveal any inflammatory tissue However, the roentgenographic changes were typical of a destructive inflammatory disease of the joint

Of these eight patients, one presented a picture of multiple soft-tissue abscesses and roentgenographic evidence compatible with

Fig 2

Fig 3

Fig 2 L L , December 29, 1945 Right joint completely obliterated by osseous trabeculations Left sacro-iliac joint apparently healed by "fibrous ankylosis"

Fig 3 W C , March 15, 1937 Complete bony ankylosis through mid-portion of the joint, with apparent quiescent destructive lesions above and below fused area

Fig 4-A

Fig 4-B

Fig 4-A A H, May 4, 1937 Destruction has occurred superiorly and inferiorly, with a sequestrum in the inferior cavity Apparent early fusion is seen through mid-portion

Fig 4-B November 20, 1937 Sequestrum is becoming absorbed Fusion apparently not solid through mid-portion of joint

Fig 4-C

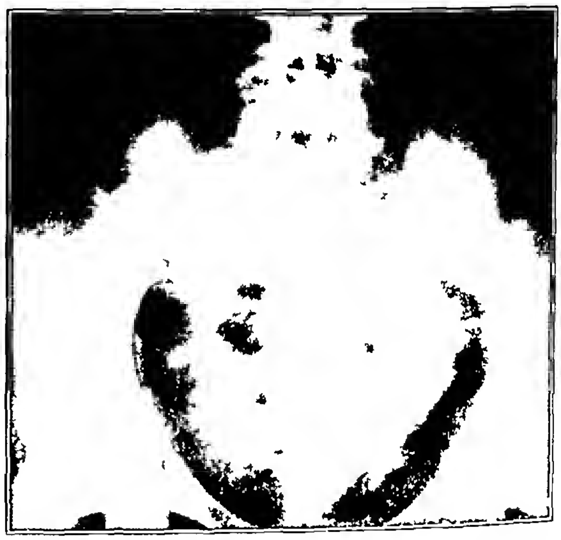

Fig 4-D

Fig 4-C June 9, 1938 Sequestrum has become absorbed

Fig 4-D January 10, 1939 Outline of destructive area in sacrum and ilium marked by sharp outline (healing) Joint completely fused above by bone

non-specific metastatic osteomyelitis in several long bones Her clinical course suggested a pyogenic infection rather than one of tuberculous origin One biopsy specimen, taken from a draining sinus tract over the sacro-iliac joint, was interpreted initially as showing a mixed tuberculous-pyogenic infection, and the patient was admitted to the Sanatorium Further review of this specimen failed to show positive evidence of tuberculosis At no time was the acid-fast organism isolated

Bacteriological proof of tuberculosis was obtained from sinus material in one of the remaining four patients These patients had had roentgenographic evidence of destruction of the joint with or without sequestration (Figs 3, 4-A, 4-B, 4-C, and 4-D), prior to complete or partial obliteration of the joints by osseous trabeculation In no patient in the series was autopsy material available

Thus seventeen patients had fusion of one sacro-iliac joint by bony ankylosis, which was either present at the time of admission or developed while the patient was under

observation In fourteen (61 per cent) the joints fused spontaneously without operative intervention

Six patients (26 per cent) showed no evidence of joint fusion Of this group, two died early in the course of the disease, in two the infection is apparently quiescent without evidence of osseous union, and two show progressive narrowing of the joints without destruction

The part played by secondary invaders in the promotion of bony ankylosis in any individual case is difficult to determine However, the presence or absence of sinuses did not alter the apparent tendency of the joint to become obliterated by osseous union (One patient with sinuses and two patients without sinuses had operative fusion of the joints)

Patients with Sinuses		*Patients without Sinuses*	
Joint fused	4	Joint fused	13
Joint not fused	2	Joint not fused	4

In all but two of the cases reviewed, active tuberculosis was bacteriologically proved The vast majority of the patients were seriously infected by the involvement of other organs, few of them entered a sanatorium because of active disease of the sacro-iliac joint alone We have grouped the patients according to a classification similar to that outlined by Cleveland

Group A Patients with a healed primary pulmonary lesion, but no associated tuberculous involvement
Group B Patients with *only* associated active pulmonary disease
Group C Patients with no pulmonary disease, but with other active foci of involvement
Group D Patients with active pulmonary disease plus other foci

Twenty-one of the twenty-three patients fall into *C* and *D* classifications (Table I) (In twenty of these patients, because of their generalized tuberculosis operation was deferred, and thus they form an excellent group in which to study the terminal history of the local disease)

TABLE I

Group	Total	Died	Living and Well	Living but Ill Good Prognosis	Poor Prognosis
A	1		1		
B	1		1		
C	6	1	1	2	2
D	15	8	5	1	1
Totals	23	9 (39%)	8	3	3

DISCUSSION

It is impossible to make any definite conclusion as to the cause of the obliteration in the sacro-iliac joints In all but two patients, tubercle bacilli were isolated from some lesion in the body One of these two had a primary lesion, and in the other the disease process was apparently due to a widely disseminated pyogenic infection In only four patients did material aspirated from the sacro-iliac lesion or from an accompanying abscess reveal acid-fast bacilli In only one other was such a diagnostic test attempted Thus these findings do not justify the definite conclusion that tuberculosis is the etiological factor in these cases The presumptive evidence, however, is that these lesions are of tuberculous origin

Patients with bilateral lesions were eliminated in order to rule out early spondylitis rhizomelica In no patient did changes characteristic of this disease supervene throughout the entire follow-up period The vast majority of patients (twenty-one) are in an age group

in which spontaneous obliteration of the sacro-iliac joint does not occur[2,3,7]. Although in many patients the joints became ankylosed while at complete rest, it is difficult to conclude that rest itself produced the change. If this were the primary factor, it is unlikely that selective obliteration of one joint would have resulted. This is particularly true where the obliterated joint showed an accompanying or antecedent destruction.

Thus the etiology lies between a low-grade pyogenic infection and one of tuberculous origin. In only one case was it felt that a pyogenic agent was the sole etiological factor. Even though in seventeen patients no material was obtained from the joint and no positive diagnosis was made, the presence of widely disseminated tuberculous lesions elsewhere in the body is strong presumptive evidence that the origin of this lesion is tuberculous. It is on the basis of this presumption that these findings are reported. It is hoped that further observations will be stimulated in order that a natural terminal history of sacro-iliac tuberculosis without operation may be recorded, and that, with larger series, the value of the operative treatment will become established.

Because of the relative rarity of the condition, alternate case comparison, similar to the work of Finklestein and his associates on Pott's disease, does not seem feasible.

Three patients who had operative fusion of their joints were included in this series in order to determine, if possible, whether the operation would be indicated from the point of view of lowering the period of hospitalization and convalescence. Operative fusion in this institution is used as a method of immobilizing and obliterating the joint after the infection appears to be under control, and not as an immediate form of therapy. The patients upon whom the operation was performed were in good general condition and demonstrated evidence of healing, both of the local and disseminated lesions. In contrast, those who had no operative intervention had, for the most part, widely disseminated tuberculosis and were in poor general condition. A comparison of the length of hospital stay would be a poor criterion, therefore, for the establishment of the efficacy of the fusion operation.

It was impossible to compare the earliest evidence of fusion in these two groups, for the operation itself so distorted the contour of the joint roentgenographically that accurate early interpretation was impossible. The authors feel, therefore, that no conclusion can be drawn in this small series as to the efficacy of the operation in shortening the convalescence and in promoting osseous union.

After those patients had been eliminated in whom the sacro-iliac joint was ankylosed on the initial roentgenogram, spontaneous fusion of the joints occurred in six patients while they were under hospital observation. The earliest fusion occurred approximately four months after the onset of symptoms; the longest interval required was approximately two years.

Should the interpretation of these findings be correct, it is the authors' feeling that a program based on approximately one year of conservative therapy should be instituted before operative fusion is contemplated. Should the sacro-iliac joint appear at the end of that time to be approaching what might be termed "fibrous ankylosis", bone-graft surgery could then be performed. It is the authors' impression that those joints which are obliterated by bone have a better chance of maintaining a permanent arrest of their tuberculosis.

Seddon has stated that his only criterion for fusion of this joint (for he is prone to accept "fibrous ankylosis" as a good terminal result) is a tendency for subluxation of the joint in the presence of marked destruction. Seddon and Strange, in their review of 176 cases of sacro-iliac tuberculosis, were able to analyze by late roentgenograms only fifteen patients who were not submitted to fusion operations. Of this group, eleven progressed to solid bony ankylosis of the sacro-iliac joint, four to what they described as "fibrous ankylosis". From this information they questioned the advisability of operative therapy. Conservatism in the handling of this problem has been concurred in by Langston and by Sisefsky.

CASE REPORTS

A. K., No. 562112. A white male, aged twenty-eight, was admitted to the Sanatorium on January 16, 1945 (Fig. 1). He had had pain in the lower back with sciatica on the left, nine years before admission. The symptoms had lasted one and one-half years and there had been no recurrence. Treatment had consisted of a sacro-iliac belt and osteopathic manipulations.

Associated lesions were tuberculosis of the right hip (proved bacteriologically), and moderately advanced pulmonary tuberculosis.

The patient's right hip fused spontaneously after immobilization in a hip spica. He was discharged as well from the Sanatorium in January 1947.

L. L., No. 271017. A white male, aged twenty-seven, was admitted in 1942. He had had pain and disability in the right hip for one year, but no symptoms referable to the sacro-iliac joints.

Associated tuberculous lesions: tuberculosis of right and left hip joints (the right was fused in 1946, the disease in the left developed in 1946), renal tuberculosis, healed rib and costochondral tuberculosis, lumbosacral Pott's disease (Fig. 2).

Left hip-joint disease developed after fusion of the right hip in 1946. The patient had early evidence of renal insufficiency. He has been immobilized in a hip spica since admission.

W. C., No. 396652. A white male, aged thirty-three, was admitted on February 5, 1937. Intermittent, ill-defined pain had been present over the right sacro-iliac joint for six months.

Associated tuberculous lesions: Pott's disease of the ninth, tenth, eleventh, and twelfth thoracic vertebrae, questionable transverse myelitis, tuberculosis of the right shoulder, with sinus drainage, bilateral tuberculous epididymitis and seminal vesiculitis, tuberculosis of the left kidney, and tuberculous urethral stricture (Fig. 3).

The patient died on February 7, 1941, from renal insufficiency.

A. H., No. 397580. A white woman, aged twenty, was admitted on February 23, 1937. Pain had been present in the right lower back for approximately eight months. She had received deep roentgenotherapy for a condition diagnosed as "sacro-iliac malignancy". An abscess was present without sinus over the joint.

Associated tuberculous lesions: a minimal amount of active pulmonary tuberculosis, tuberculous nephritis, tuberculous endocervicitis, and tuberculosis of the knee (Figs. 4-A, 4-B, 4-C, and 4-D).

Treatment consisted of frame immobilization. When the patient was last seen, in 1939, her non-protein nitrogen was slightly elevated. The knee had healed by fibrous ankylosis.

NOTE: The authors wish to thank E. W. Lahoe, M.D., and Carl E. Badgley, M.D., for their assistance in preparing this paper, and John F. Holt, M.D., for reviewing and confirming the roentgenographic interpretations.

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BLADE-PLATE FIXATION IN NON-UNION AND IN COMPLICATED FRACTURES OF THE SUPRACONDYLAR REGION OF THE FEMUR

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The treatment of non-union and of some acute fractures of the supracondylar region of the femur is often extremely difficult by the usual types of fixation In November 1946, at the Interurban Orthopaedic Society, Dr Hugh Thompson described the use of the blade-plate (Moore-Blount) in a patient with an acute supracondylar fracture of the femur, upon whom he had operated in the fall of 1943 In August 1946, the authors used this method in the first of three cases, without knowledge of Dr Thompson's experience, although with the realization that this type of fixation had been used in other clinics for supracondylar osteotomies Dr Thompson has kindly submitted his case, to be added to our cases, in this publication

The method to be described is not advocated for all cases of fracture or non-union in the supracondylar region It is indicated in those cases in which failure or difficulty is anticipated by the more generally accepted techniques Although this procedure is not without hazard, we believe that in selected cases it has advantages over other types of fixation This has been noted particularly in old cases of non-union with considerable osteoporosis of the condyles The condyles are comprised of cancellous bone and are subject to osteoporosis of both the reflex and disuse types Often in long-standing cases of non-union, the condyles are so soft that screws will not hold Another difficulty in cases of non-union is the development of intra-articular adhesions in the knee joint These may bind the short distal fragment so firmly to the tibial condyles that the long lever of the

Fig 1-A

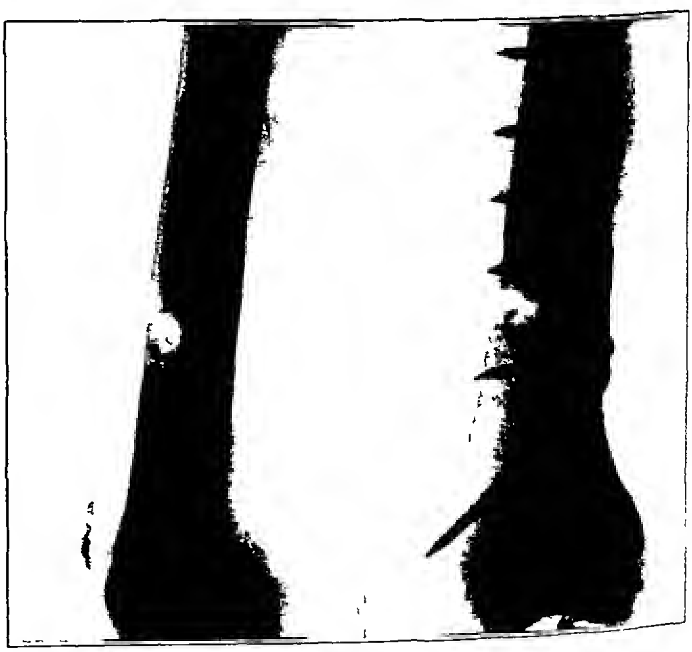

Fig 1-B

Fig 1-A Case 1 Preoperative roentgenogram shows displaced supracondylar fracture

Fig 1-B Postoperative roentgenograms reveal excellent alignment and fixation by blade-plate Early callus is present

leg causes motion to occur more readily at the fracture site than through the knee joint. Even with the extremity in a cast or in traction, this factor may prevent union or may allow malunion to develop.

The blade-plate method can also be used to advantage in T-shaped condylar fractures in which the condyles cannot be controlled by external means. Although some length may be lost by this technique, the advantages of normal alignment, rigid fixation, and early knee motion far outweigh this disadvantage. If other complications are present, such as intracranial lesions, multiple fractures, or senility, the use of the blade-plate will avoid confining the patient to bed. Its advantage in the aged is the same as in fractures about the hip in which this and similar types of fixation are in common usage.

TECHNIQUE

An anterolateral incision is made, so as to approach the lower third of the femur between the rectus femoris and vastus lateralis and through the vastus intermedius. The incision is

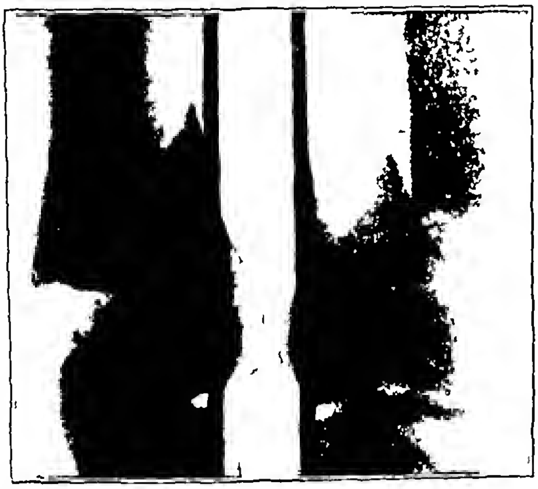

FIG. 2-A

FIG. 2-B

Fig. 2-A: Case 2. Roentgenograms show compound, comminuted supracondylar fracture with loss of bone substance.

Fig. 2-B: Condition of fracture when seen by authors, six weeks after injury. Bone defect, inadequate fixation, and distraction are present.

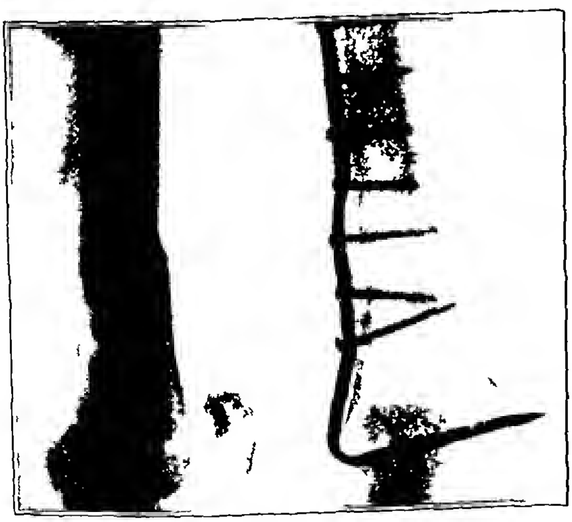

FIG. 2-C

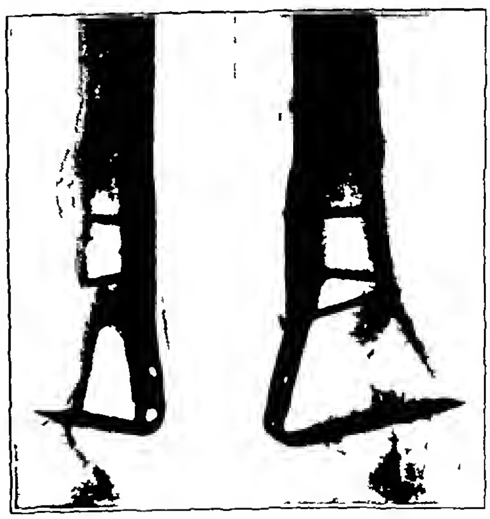

FIG. 2-D

Fig. 2-C: Roentgenograms show early callus and union, six weeks after blade-plate fixation.

Fig. 2-D: Eighteen months after blade-plate fixation.

carefully extended distally through the suprapatellar pouch and into the knee joint, the standard anterolateral incision of the knee being used. The lower third of the femur and the entire fracture site are exposed by subperiosteal disssection, the suprapatellar pouch being carefully stripped from the femoral fragments so that it can be completely and normally reconstructed in closure. If the fracture or non-union extends through the intercondylar notch, the condyles are first approximated by long screws or threaded pins. If non-union is present between the condylar fragment and the shaft, the scar and fibrous tissue are resected down to normal bone and the fragments are approximated, if possible in an oblique plane or in the manner of a step-cut. If the condylar fragment is extremely short or if the metaphyseal portion is severely comminuted, it may be necessary to telescope the diaphyseal fragment a short distance into the condyles to assure maximum contact. Although some length may be lost, it may be well worth the sacrifice to obtain earlier and more certain union. After reduction has been obtained, the plate portion of the blade-plate is bent to conform to the lateral surface of the condyles and femur. The blade is driven across from the lateral surface, so that the shaped plate conforms exactly to the lateral femoral surface. At all times the blade-plate should be subsynovial and subperiosteal to ensure as little interference with knee function as is possible. When the plate has been screwed to the femur, one is impressed by the extreme rigidity of the fixation. At this point intra-articular adhesions, if present, can be cut. The synovial lining of the suprapatellar pouch and knee is carefully restored and closure is effected in layers.

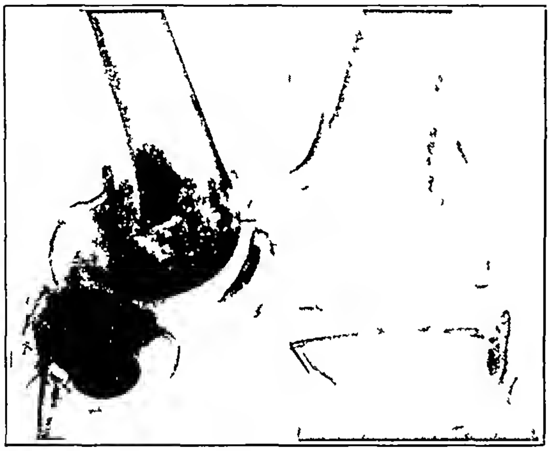

Fig. 3-A

Case 3. Roentgenograms show comminuted T-shaped condylar fracture. An old depressed fracture of the lateral tibial plateau, with internal fixation, is present. Arthritic changes may be seen on tibial surface.

Early motion of the knee is encouraged as soon as the wound has completely healed. If necessary, in cases of non-union, motion may be started in balanced traction. In fresh fractures of the aged, early ambulation with crutches may be indicated to prevent pulmonary complications. Union should be solid in three to four months.

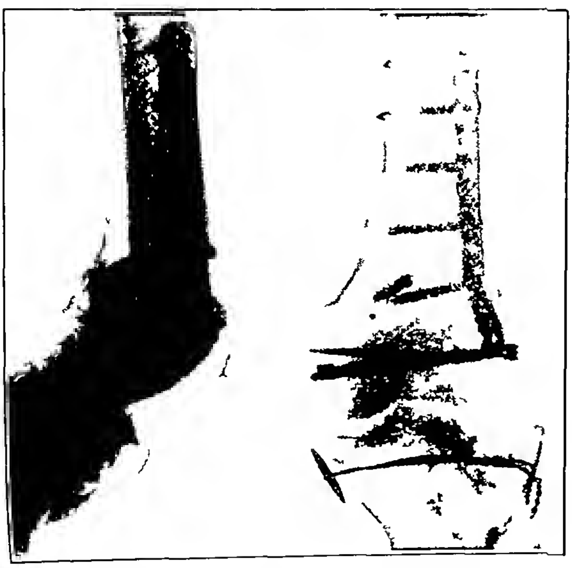

Fig. 3-B

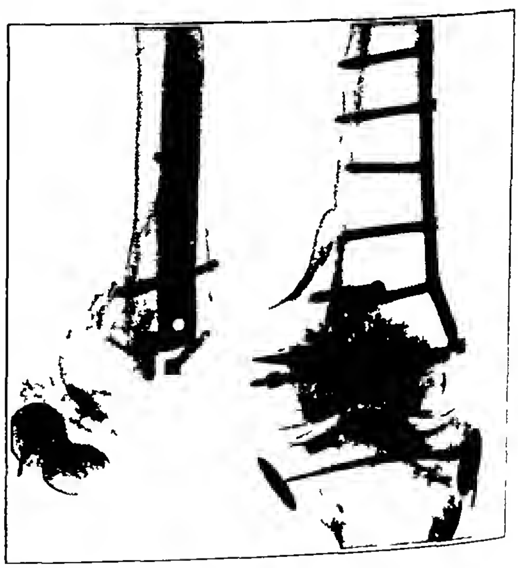

Fig. 3-C

Fig. 3-B. Three months after blade-plate fixation, union is solid.
Fig. 3-C. Condition of fracture twelve months after operation.

CASE 1*. In the fall of 1943 a man, twenty-two years old, had sustained a supracondylar fracture of the right femur (Fig. 1-A) and a fracture of the shaft of the left femur, in addition to severe head injuries which had produced unconsciousness for two weeks. The patient was seen by Dr. Thompson three weeks after the accident. At this time his mental condition had cleared, but little had been done for the fractures other than to protect them in Thomas splints.

Because it was considered unsatisfactory to keep both lower extremities in splints, the right femur was fixed by a blade-plate (Fig. 1-B). Dr. Thompson thought that a form of fixation was desired which would not require external support. The extremity was splinted for ten days, while the operative wound healed. After this time no form of external fixation was used, and the patient was encouraged to flex the knee while in bed. The patient obtained a fine functional result, with no deformity or disability.

CASE 2. On August 1, 1946, a man, thirty-nine years old, sustained a severe compound fracture of the lower third of the left femur (Fig. 2-A). A portion of the femoral articular surface had been lost through the open wound, as had a large bone fragment from the fracture site. The wound healed primarily, following débridement and plate fixation.

The authors first saw the patient on September 20, 1946, when roentgenograms disclosed non-union with loss of a large bone wedge from the fracture site posteriorly; the fragments had been distracted by the plate (Fig. 2-B). Exploration and fixation with a blade-plate were performed four days later. At operation, because of loss of bone substance, telescoping of the proximal fragment into the distal fragment was necessary. Rigid fixation was obtained by a blade-plate. Knee exercises in balanced traction were started early. Six weeks after operation, roentgenograms showed early union (Fig. 2-C). Motion was present from 180 to 160 degrees. Weight-bearing in a brace was started. Four months later union was solid and all support was removed. Active motion was possible from 180 to 160 degrees.

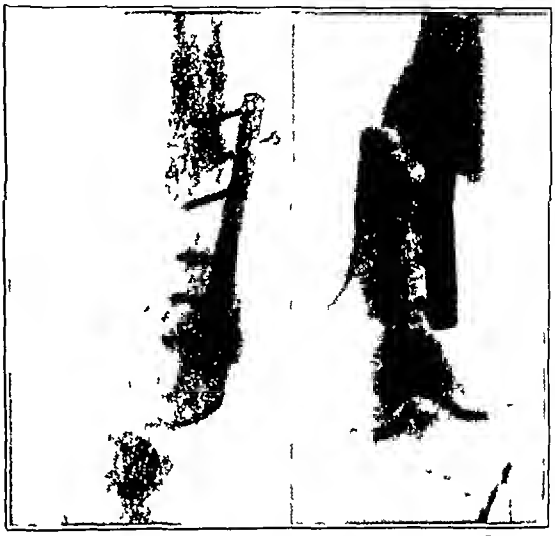

FIG. 4-A

Case 4. Roentgenograms at the time of initial examination show non-union with evidence of infection, sclerotic bone ends, loosened plate and screws, and a plate extending into the suprapatellar pouch.

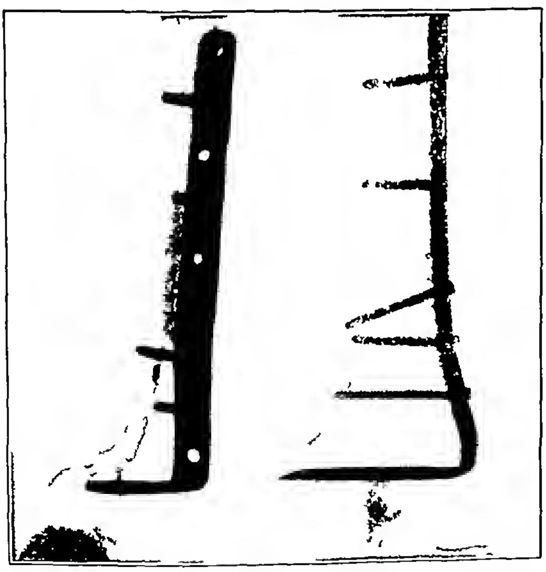

FIG. 4-B

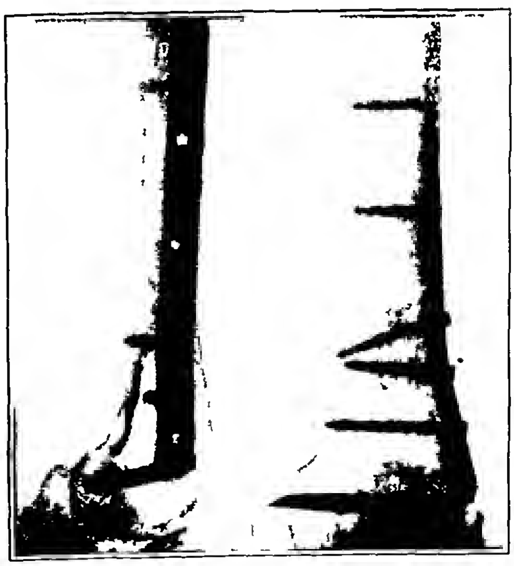

FIG. 4-C

Fig. 4-B: Two months after fixation with blade-plate, roentgenograms show early union with normal alignment.

Fig. 4-C: Five months after fixation, union is completely solid.

* Case of Hugh Thompson, M.D.

The patient was not seen again until a year later (Fig 2-D) At that time he was completely free from pain Active motion was present from 180 to 150 degrees, and there was an inch and a half of shortening Limitation of motion was thought to be due to the partial avulsion of articular cartilage at the time of injury

CASE 3 On October 19, 1946 a forty-year-old man sustained a comminuted T-shaped condylar fracture of the left femur (Fig 3-A) Previously (in April 1942) he had suffered a depressed fracture of the lateral tibial plateau in the same knee, this had been operated upon elsewhere Because of the arthritic changes in the knee as a result of the old fracture, open reduction with blade-plate fixation was elected to effect early joint mobilization and to restore the condylar relationship Open reduction was done on October 25, 1946, and the condyles were approximated with two threaded pins, placed transversely Because of severe comminution with small fragments, the proximal portion of the shaft was telescoped into the condyles Blade-plate fixation was used Knee exercises in balanced traction were started, and the patient was discharged with partial weight-bearing, six weeks after operation

Solid bony union was present three months after operation (Fig 3-B) Motion was present from 175 to 90 degrees One year later there was motion from 180 to 75 degrees and one inch of shortening The patient works in a lumber mill and his only discomfort is mild aching after sitting for long periods (Fig 3-C)

CASE 4 A nineteen-year-old girl was first seen in January 1947, with an infected, draining, supracondylar fracture of the left femur, which she had sustained eight months previously The fracture had been plated elsewhere and a postoperative infection had developed The distal end of the plate had been placed in the suprapatellar pouch (Fig 4-A) Frank non-union was present and the knee joint was infected The patient's condition was toxic and she had a septic fever After the administration of penicillin and many transfusions, the plate and sequestra were removed on January 3, 1947 The wound healed primarily For three months the extremity was immobilized in a single spica On May 2, with penicillin therapy, the knee joint and the lower third of the femur were explored through an anterolateral incision Many intra-articular adhesions were found and sectioned The bone ends were freshened in an oblique plane and fixed with a blade plate Knee motion was started in a hinged Thomas splint The patient was discharged one month after operation in a toe-to-groin brace, passive motion was possible from 180 to 150 degrees (Fig 4-B) Five months after operation the brace and crutches were discarded, as the roentgenograms showed solid bony union (Fig 4-C) Eight months after operation the knee was completely free from pain She had passive motion from 180 to 95 degrees and active motion from 165 to 95 degrees Three-quarters of an inch of shortening was present The patient thought she was still improving

CONCLUSIONS

Blade-plate fixation in selected cases of non-union and of complicated fresh fractures of the supracondylar region of the femur has definite advantages, including rigid fixation, early joint mobilization, and, in the elderly, early ambulation with crutches

The four cases presented illustrate the use of the blade-plate in cases of

1 Simple supracondylar fracture complicated by multiple other fractures and head injury,

2 Comminuted non-union or prospective non-union, complicated by the loss of bone substance at the fracture site,

3 A comminuted T-shaped condylar fracture with rotation of the condyles, considerable comminution, and arthritic changes as a result of a previous fracture,

4 Old infected non-union with intra-articular adhesions and infection of the knee joint

THE SYNOVIAL MEMBRANE OF THE KNEE IN PATHOLOGICAL CONDITIONS

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Translated by Emanuel B. Kaplan, M.D., New York, N. Y.

The surgeon who opens the knee joint finds frequently that changes have occurred in the synovial membrane. The membrane may be excessively thickened, or it may present changes in color and appear pink, red, or purple. In other instances its character may be changed, and the scalpel cuts into resistant elastic tissue instead of the ordinary soft synovial membrane.

Gross inspection does not permit one to appreciate the nature of the changes. The anatomical studies of Testut, Poirier and Charpy, Mouchet, and Lévêque do not furnish any information on the importance of the synovial membrane, on its precise topography, or on the distribution of the synovial folds. For example, it is impossible to learn the average weight of the infrapatellar fat pad. This is easy to understand, because the synovial membrane is an unstable organ, varying according to the age and obesity of the individual and depending upon conditions at the time of observation (whether in motion or at rest, with static or distinct pathological factors).

Only microscopic studies, in our opinion, can help us to understand the pathological conditions.

NORMAL SYNOVIAL MEMBRANE

The histology of the normal synovial membrane was a subject of investigation by Hammer and by Braun toward the end of the nineteenth century. In recent years it has been studied by Efskind, Franceschini, Granel, Key, Kuhns, Magnus, Marquort, Mayeda, Policard, Raszeja, and Rouvière. Numerous problems were involved, concerning especially the aspect of the cells covering the articular wall, their role, and their origin. It now appears to be accepted that:

1. The synovial membrane is derived from the mesenchyma; it is neither epithelium nor endothelium.

2. The functions formerly attributed to it, such as filler of the joint, source of reserve fat, and protector from injury in motion, are of secondary importance. The synovial membrane functions actively in a manner similar to that of the reticulo-endothelial tissues.

3. The varying morphology of the synovial membrane, with some zones rich in cells and others with few cells, represents only an adaptation to mechanical or pathological conditions.

The author has adopted the histological classification suggested by Key. The various aspects of the synovial membrane are not classified as to the number of surface cells, but according to the nature of the subjacent layers. Key divided them into: (a) an adipose type, covering the articular fat pads, (b) a fibro-areolar type, overlying areas subjected to moderate pressure and pull, which are the principal sites of villi, and (c) a fibrous type, covering ligaments and tendons. We could add to this group a *muscular* type, covering the suprapatellar pouch. In the present study, special attention has been given to the infrapatellar adipose type, for many reasons.

In the course of an operation, it is easy to remove a piece of the infrapatellar fat pad. The site of the removal is fairly constant. The adipose synovial membrane appears to be affected early by the pathological process; all surgeons have observed an enlargement of the infrapatellar fat pad in affections of the menisci. Finally, in examining the fat, which is the most ordinary tissue of the joint, we can easily confirm the reactions of the synovial membrane.

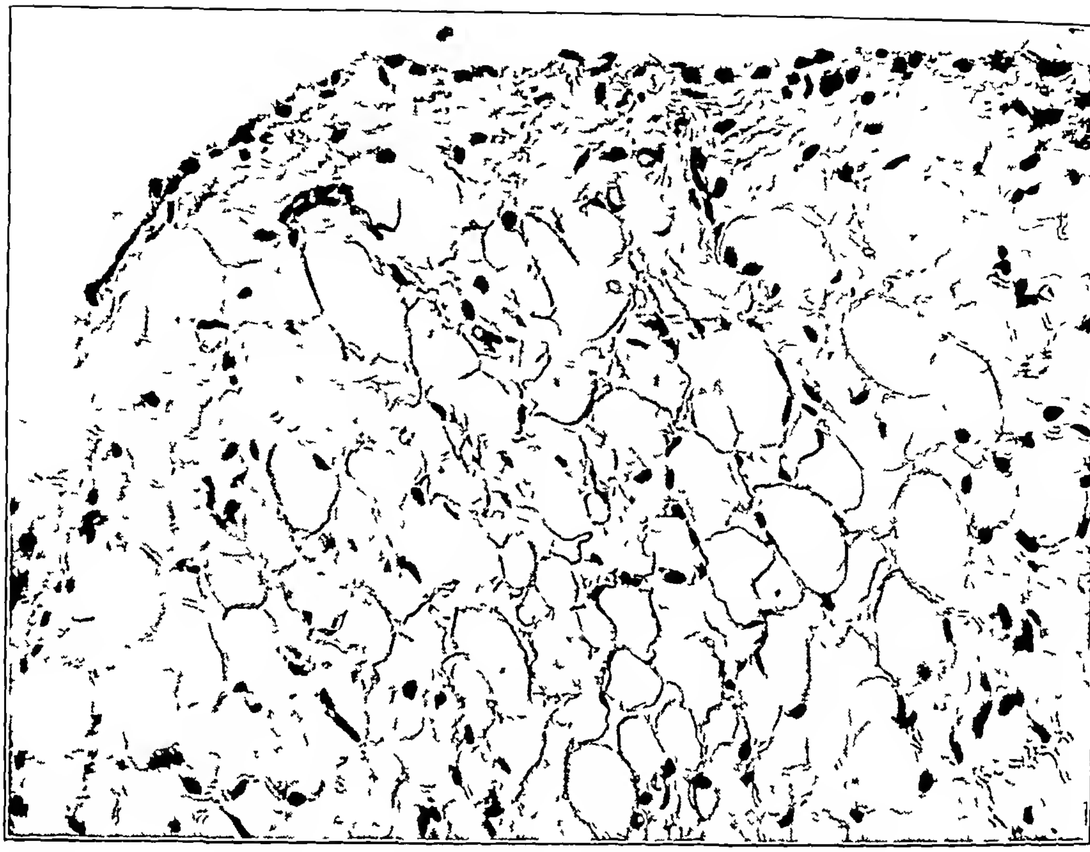

FIG 1
Adipose synovial membrane of a stillborn infant (× 250)

Observations in Normal Man and the Normal Animal

The observations in this study confirm the description of Key The adipose synovial membrane consists generally of a single internal layer of cells, resting on an external adipose layer (Fig 1) The cells of the intima are flattened out, fairly well spaced, and separated by an interstitial, homogenous, non-fibrillar substance which shows the characteristic staining reactions of collagen The external layer is formed by typical adipose tissue, crossed by fine collagenous fibers Small capillaries, by joining the two layers, form a wide-meshed network A few larger vessels are seen in the external layer

The findings just described are also found in the rabbit (Fig 2)

In certain preparations the intima has a multistratified appearance, as a result of obliquity of the section The articular border, instead of being continuous, may be lacelike Sometimes the cells and the intercellular substance seem to separate and to fall into the articular cavity, this is a true process of desquamation

In some adults the adipose mass of the external layer is not uniform (Fig 3) Fine collagenous fibrils may be found between the fatty vesicles, accumulations of fibrocytes and numerous vessels are also present The presence of connective tissue in the adipose mass is considered a sign of aging It will be necessary to differentiate this condition from true pathological fibrosis Finally, it may be noted that free cells are rare in the adipose synovial membrane, although occasionally a plasmocyte or lymphocytes may be encountered

PATHOLOGICAL CHANGES IN THE SYNOVIAL MEMBRANE

To understand the behavior of the synovial membrane in pathological states, we excluded from this study all diseases affecting the diarthrodial cartilage or bone (such as osteo-arthritis or chondromatosis), and those due to micro-organisms (tuberculosis or septic arthritis) or to tumors

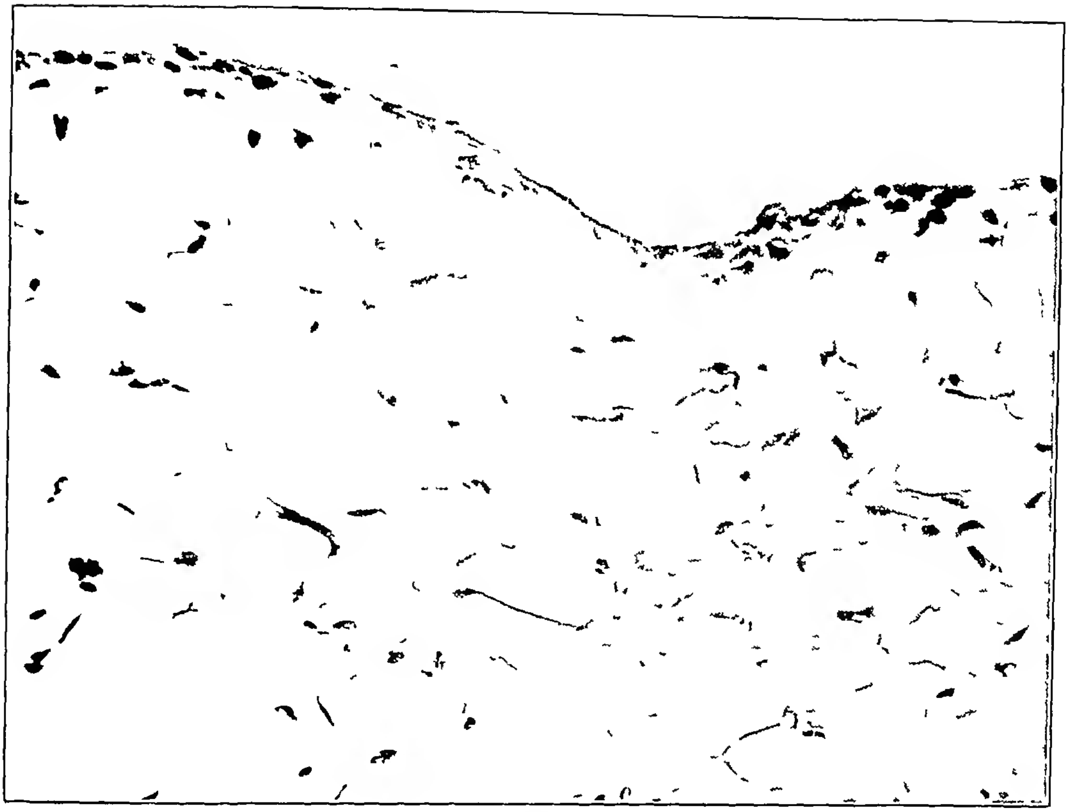

FIG. 2

Normal adipose synovial membrane of a rabbit (× 250). The intima consists of elongated connective-tissue nuclei, irregularly arranged in the free border; the basal substance is amorphous. The external layer contains typical fat tissue.

FIG. 3

Adipose synovial membrane of a young adult (× 250). Mild fibrosis of the adipose layer is present. The density of the nuclei of the intima is due to the obliquity of the section. There is desquamation of the cells of the free edge.

I. *Rupture of the Menisci*

Review of Literature

Roux of Lausanne, in 1895, maintained that there is a disease of the menisci,—namely, meniscitis. He found, in 1926, an irritative infiltration ("*infiltration réactionnelle*"), overlying the border of the meniscus.

Patry of Aarau (Switzerland) supported an analogous view in 1926. He stated that the histological examination of pieces of degenerated (*modifié*) synovial membrane confirms the existence of a chronic inflammatory process with infiltration of migratory cells, connective-tissue proliferation, and hyperaemia with vascular neoformation.

Bircher, in 1933, noted that changes of the meniscus affect the fat pad equally, qualitatively and quantitatively, and he wondered what relation could exist between the lesion of the meniscus and that of the synovial membrane.

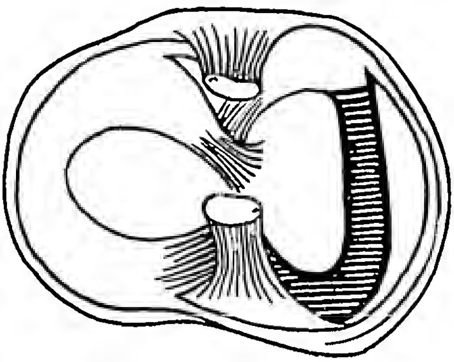

FIG. 4-A

FIG. 4-A. Bucket-handle tear of the medial meniscus of forty-eight days' duration in a miner, thirty-five years old. Drawing of medial fibrocartilage with separation of a large portion, adherent to the anterior and posterior horns and displaced toward the interior of the joint. The lines indicate the portions of the anterior horn and of the meniscus which were removed.

FIG. 4-B. Photograph of the specimen removed.

FIG. 4-B

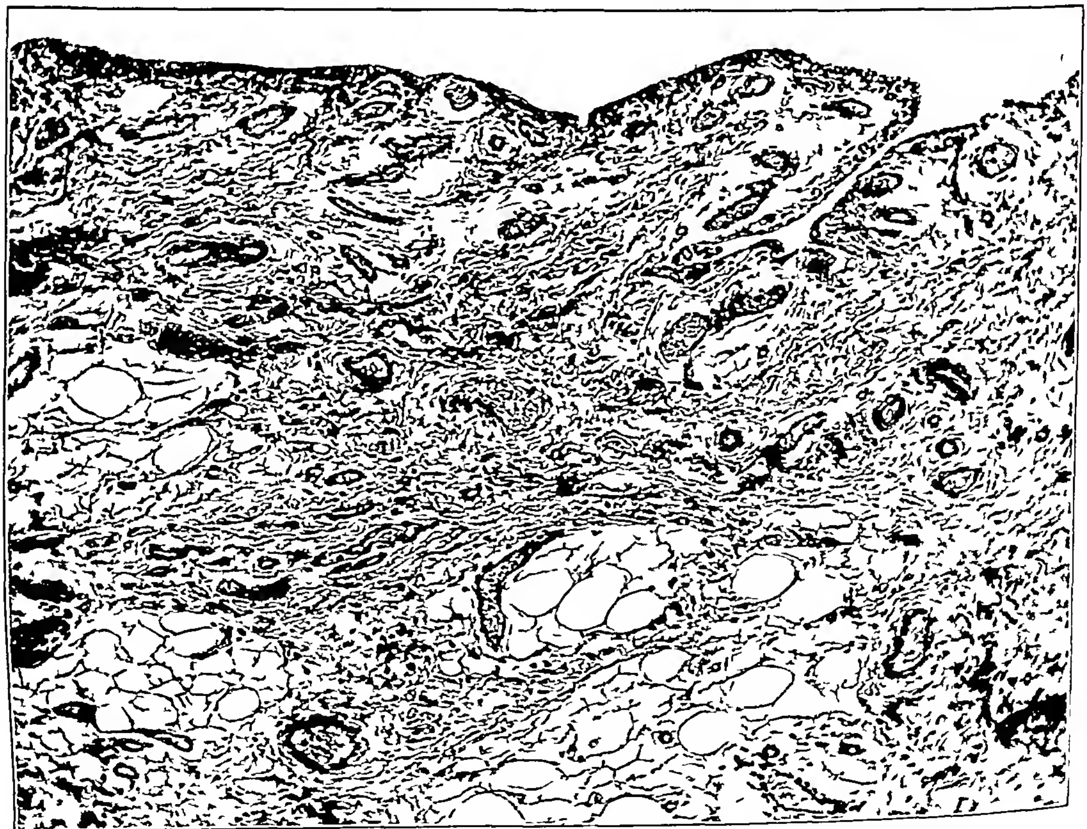

FIG. 4-C

Adipose synovial membrane (× 75) with marked fibrosis, many cells, and many vessels. The outermost layer constitutes a thick-walled partition. Note the villus.

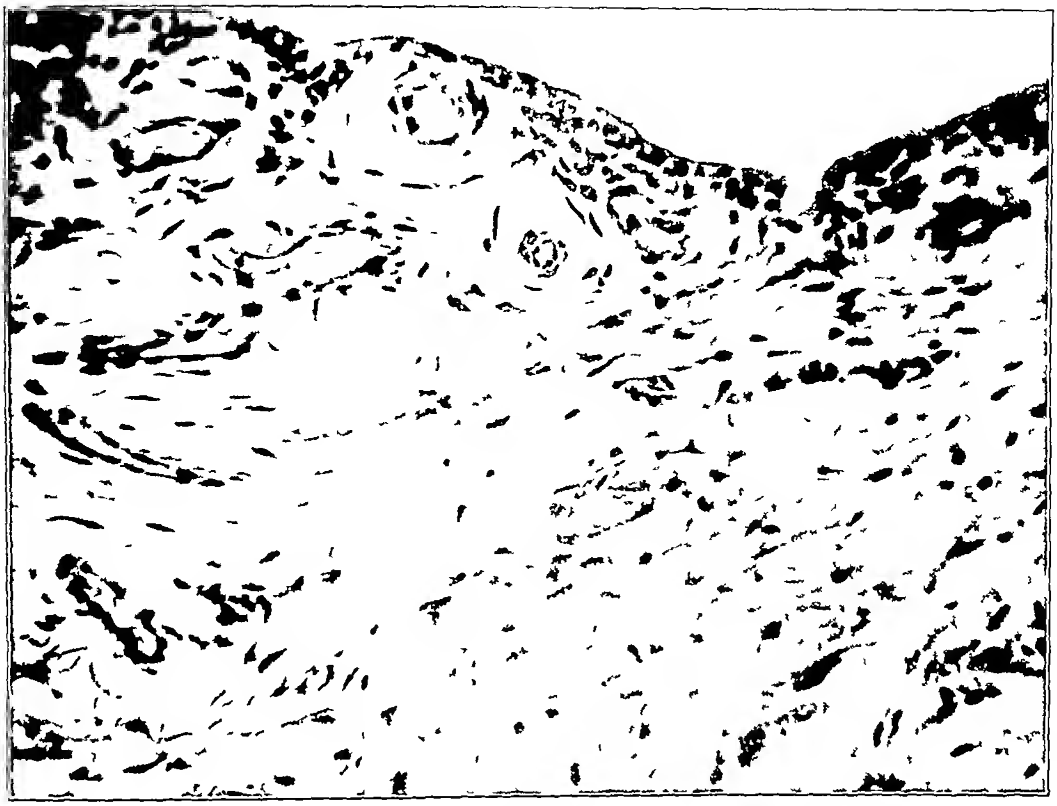

FIG. 4-D

Detail of Fig. 4-C (× 250). Shows multistratified intima. The external layer is fibrous, very vascular, and notably without fat. Little or no leukocytic infiltration is seen.

Two isolated reports, one published by Estor in 1934 and the other by Morasca in 1936, concern perimeniscitis and mention the reaction of the synovial membrane. Ceelen, in 1936, considered the repair of meniscal lesions and mentioned also the synovial membrane.

These are the only contributions we have found in the Continental literature. Since the meeting of the *Congrès Français de Chirurgie* in 1926, the theory of inflammatory meniscitis has not been recognized in Europe.

Of the literature in the English language, the article by Bristow in 1925 is noteworthy, because he presented the problem without giving a solution. A photomicrograph is reproduced to illustrate the "synovial membrane from an average case of internal derangement, showing the endothelial lining, an average number of blood vessels and the fibrous tissue stroma". This contrasts with a second photomicrograph, taken from a case of hypertrophic villous synovitis. The author emphasized the need for a more detailed histological study.

Wallace and Perman, in 1927, found that the injured meniscus acts as a foreign body, the synovial membrane reacts by proliferation, assuming the aspect of aseptic inflammation with congestion, serous exudate, cell proliferation, and constant presence of some inflammatory cells. Over the fat pad especially, the adipose cells are atrophic, marked fibrosis develops, the vessels increase in number and thickness, and diffuse "pericapillaritis" appears.

Bick, in 1930, observed changes characteristic of subacute synovitis.

Burman and Sutro, in 1933, observed incidentally in their study of meniscal degeneration: "The synovia showed frequent changes, consisting of hyperplasia of varying degree, congestion of subsynovial capillaries with a varying amount of lymphocytic infiltration, and occasional vessel alteration, as hyalinization".

In experimental studies on healing of torn or removed menisci, by Niessen, King, and Azzollini, the synovial membrane was examined only incidentally.

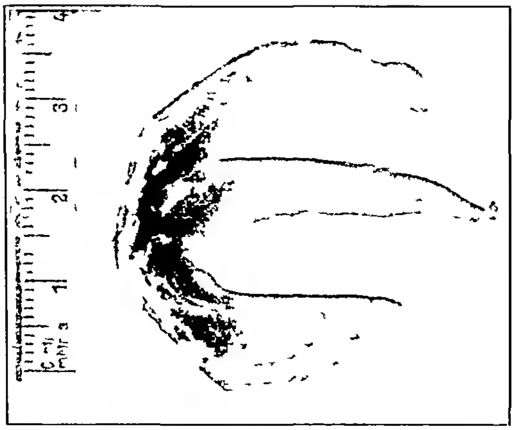

FIG 5-A

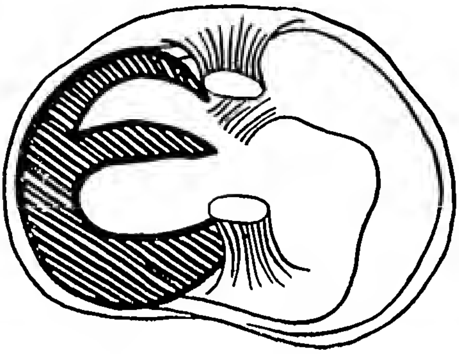

FIG 5-B

Observations in Man

We removed parts of the infrapatellar fat pads for biopsy in the course of meniscectomies. The material was classified according to the length of time since onset, as follows

Evolution of Less than a Month

If the patient is operated upon a few days after the accident, only a few histological changes are observed in the adipose synovial membrane. Slight activity of the villi may be observed, a slightly more intense vascularization, a discrete fibrosis of the adipose tissue, and the appearance of fibrocytic elements around the vessels. In view of our statement on changes in connection with aging, however, it is impossible to state that the picture is truly pathological

Evolution of Average Duration

The intima shows an irregular wavy border with large villi in some areas. It consists of two to

Fig 5-A Tear of the lateral meniscus with a transverse fragment. Tear was of thirty-four years' duration, in an individual forty-nine years old. The fragment arises from the posterior portion of the fibrocartilage and protrudes transversely into the joint

Fig 5-B Drawing of the meniscus, removed *in toto*

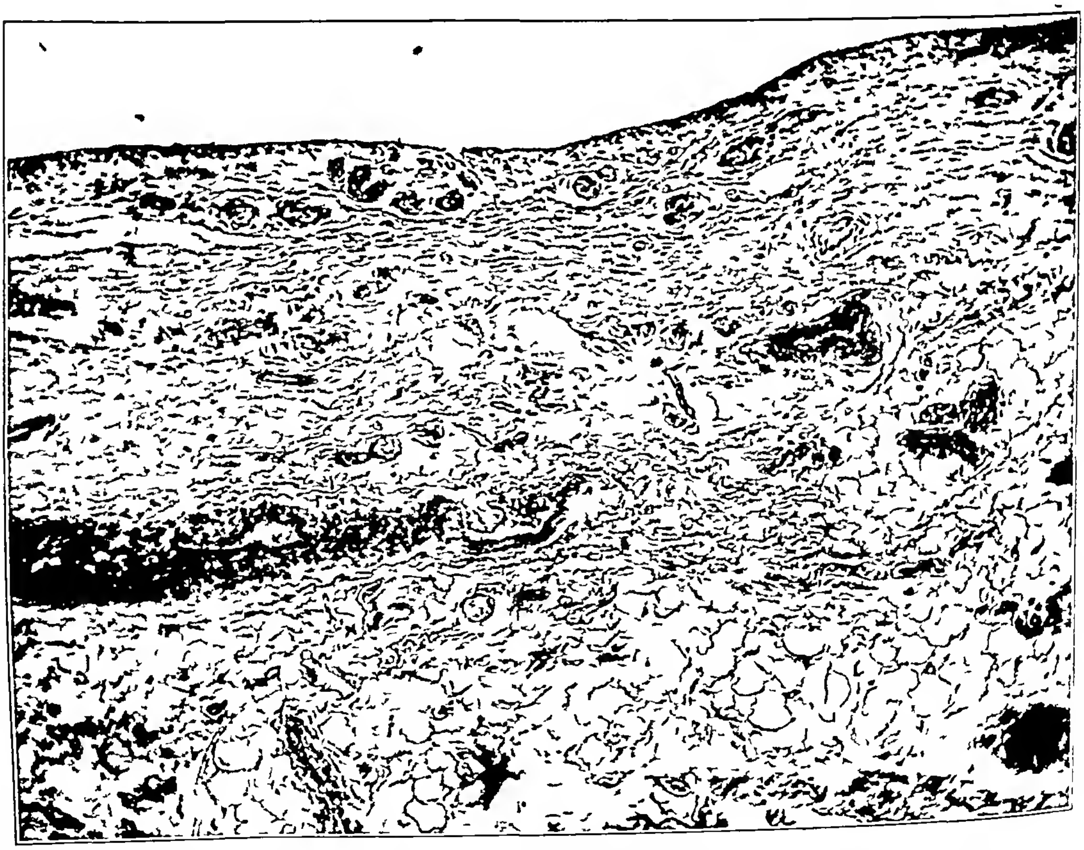

FIG 5-C

The internal layer of adipose synovial membrane (× 75) is very dense, the intermediary layer consists of a band of connective tissue with lamellae parallel to the surface, the external layer is more fibrous than adipose. The ligament is adipose in one area

five layers of nuclei, varying in form and distributed irregularly The intercellular substance consists of a network of poorly defined fibrils, bordering irregular alveoli which

Fig 5-D

Detail of the preceding section (× 250) The internal layer shows numerous nuclei, very dense stroma, and fairly large subjacent arterioles (due to hypertrophy of their muscle elements) The intermediary layer is a fibrous band with elongated nuclei parallel to the surface, rare vessels, and no important infiltration The external layer shows almost complete disappearance of fat cells

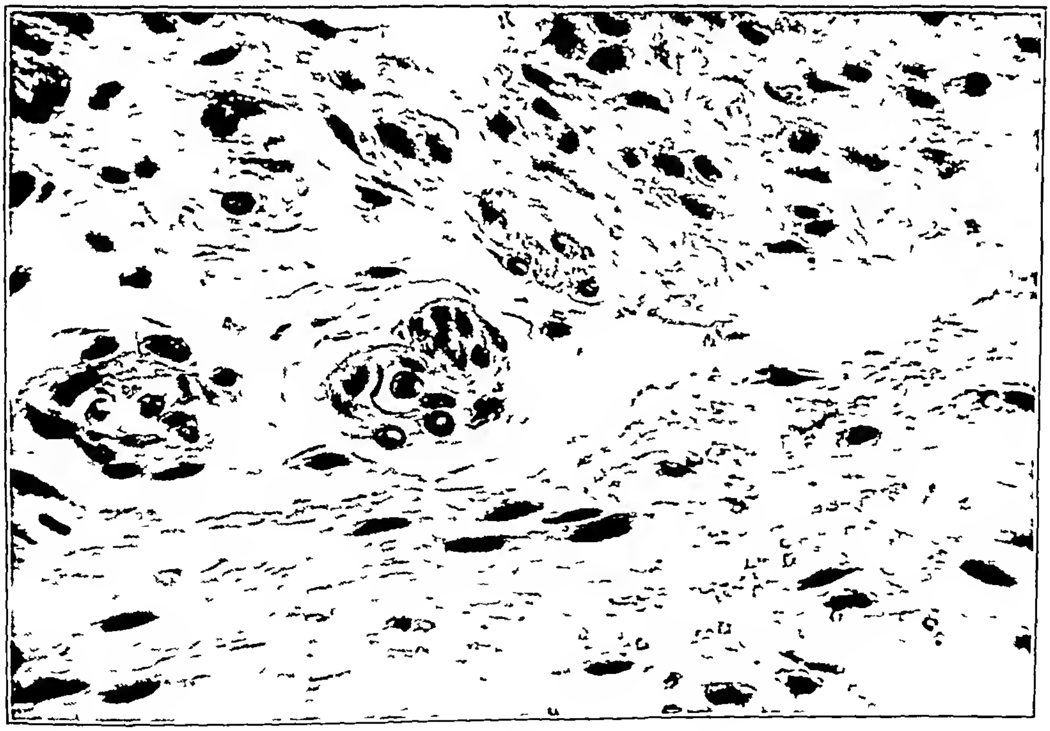

Fig 5-E

Detail of preceding section (× 625)

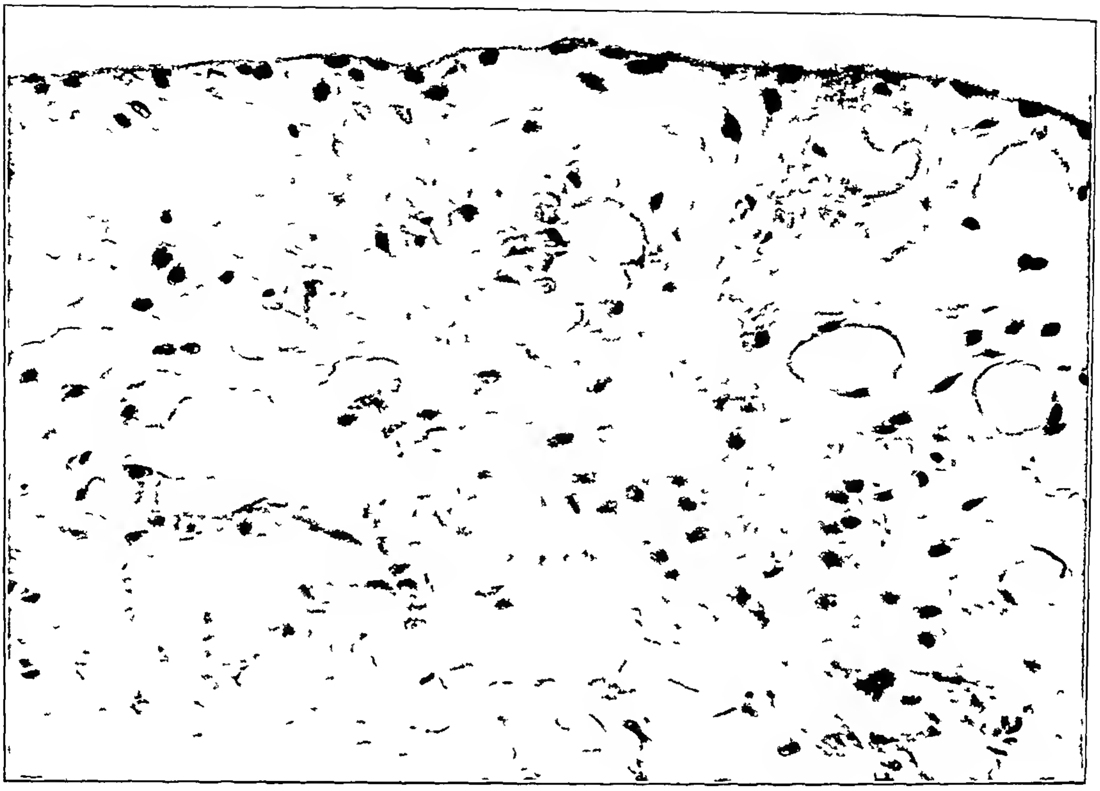

FIG 6

Forty-two days after an experimental meniscal injury in a rabbit (× 250) The internal layer has a fair number of nuclei with a dense stroma between them The external layer also shows fat vesicles, but the fibro-areolar picture predominates, the cells are mostly connective and the free cells are rare In the right upper quadrant an area of erythrocytes may be seen

appear empty At the articular surface, these fibrils appear to be crowded into a thin unraveled line The thinner and less numerous capillaries are distributed near the surface, the larger and more numerous capillaries are located deeper

The external layer is heavily laden with irregular bands of connective tissue which surround the fat lobules or vessels and which penetrate into the villi In the vicinity of some of the vessels, a few lymphocytes are found Plasmocytes are rare (Figs 4-A to 4-D)

Evolution of Long Standing (More than Six Months)

In low-power magnification, a surprising fibrosis of the fat tissue is seen This fibrosis has undergone some organization The connective-tissue lamellæ are arranged parallel to the surface so well that three layers can be differentiated,—an internal layer, as in all synovial membranes, a fibrous intermediary layer, and an external fibro-adipose layer

The intima has irregular borders, villi are rare The number of nuclei vary from two to seven, they are round or oval The fibrils of the intercellular stroma are more numerous and closer than normal Capillaries are seen frequently

The intermediary layer consists of one or two bands of fibrous tissue with lamellæ arranged parallel to the surface The nuclei are elongated Surrounding some of the vessels is a crown of small round cells In the majority of cases, the number of plasmocytes is not greater than that found in the normal synovial membrane Rarely, their number is increased, but then the history of the patient shows some complication, such as locking of very long duration, obesity, genu valgum, or pre-existing arthritis

The external layer is more adipose than fibrous Between the fat lobules are large fibrous walls, similar to the tissue of the intermediary layer (Figs 5-A to 5-E)

Observations in the Animal

Removal of the medial meniscus was performed on the right knees of eight adult

rabbits The animals were operated upon under anaesthesia The joints were closed aseptically, and the wounds healed readily

FIG 7

One hundred and two days after an experimental meniscal lesion (× 250) Note irregularity of the articular edge The intima is directly continued into the external layer All trace of fat has disappeared Compact fibro-areolar tissue is present with large vessels The majority of cells are fibrocytic in character

FIG 8

Section from rabbit, sacrificed 231 days after a meniscal injury (× 250) An amorphous substance has been deposited at the edge of the synovial membrane The internal layer is multistratified The external layer is fibro-adipose

Evolution of Average Duration (More than One Month)

Two rabbits were sacrificed on the forty-second day The fat pad of the right knee was removed, and also that of the sound left knee, for comparison

The intima consisted of a series of connective-tissue nuclei, fairly close to each other, irregularly arranged, frequently in two or more layers Between them were fine, closely placed fibrils The villi and synovial folds were more marked than in normal animals

The external layer was mostly fibrocellular In some areas it was adipose, but the vesicles were small and deformed The predominating intercellular stroma consisted of collagen fibers of variable density, sometimes collected in bands As in the intima, the majority of cells had the characteristics of fibrocytes A few mitotic figures were noted

The number of plasmocytes and of mononuclear leukocytes was reduced and usually did not exceed one cell per field The large and small vessels were numerous and were filled with red blood cells (Fig 6)

Evolution of Long Duration (More than Seventy Days)

The other animals were autopsied between the seventieth and the two hundred and thirty-first days The histological findings (Figs 7 and 8), which were practically identical, can be summed up as follows

1 Increase in number and importance of folds and villi

2 Collection of fibrinoid substance adherent to the surface of the membrane

3 Irregularities and desquamation of the intima The border has an indented appearance with "dropping" of some elements into the joint and unraveling of the basal substance

4 Hypertrophy of the internal layer, nuclei are thrown together, arranged in two or more irregular strata Stroma are thickened and dense, with fine fibrils Several capillaries are seen

5 Disappearance of the adipose tissue from the external layer In some spots the original outline can be recognized, it is replaced almost everywhere by a fibro-areolar or even by a fibrous texture Collagenous fibers, which are rare on the surface, have a tendency to organize in parallel bands in the depths

6 The majority of the elements of the superficial, as well as the deep, layer have the character of fibrocytic cells Their appearance is varied The surface cells are ovoid and somewhat swollen, at times they look like small round cells, grouped closely in the external layer These free histiocytes are rare

7 Inflammatory cells, plasmocytes and mononuclears, are equally rare Exceptionally, the plasma cells are collected in groups, resembling nodular formations

8 The blood vessels, ranging from capillaries of the intima to the large vessels of the deep layer, are filled with many red blood cells There is no leukocytic infiltration or connective-tissue reaction in the form of a crown in the vicinity of these blood vessels

Conclusions

The processes studied in man confirm the observations in the animal (the acceleration of the process in the animal must be taken into account) The findings can be summarized as follows

Stage I In the course of the first weeks after the meniscal injury, the synovial membrane shows very little change

Stage II After the first month it begins to show signs of activity (villi, irregular articular outline, stratification of the intima, and multiplication of fibrocytes), and then of progressive sclerosis (disappearance of the external fatty layer and its substitution by fibrous tissue)

Stage III Toward the sixth month in man and the third month in the animal, the processes described become more intense, especially the fibrosis, which has a tendency to

organize and to become lamellated This picture persists as long as the meniscal injury is present

In certain cases a new factor, rather discrete, may be added,—namely, differentiation of plasma cells and mononuclears

These histological facts are important to the orthopaedic surgeon, since they indicate

1 That the fat pad is actually enlarged in meniscal injuries

2 That its structure is changed It is understood that the fat is not crushed when grasped by the forceps, but rather grates when cut by the scalpel

3 That the meniscal injuries which are not operated upon have no tendency toward repair, but show progressive anatomical disorders

4 If plasmocytic and mononuclear infiltration is accepted as a sign of chronic arthritis, it is possible to state that irritation of the joint by meniscal injury sometimes produces eventually a moderate chronic arthritis

5 That the theory of the followers of Roux, that meniscitis or perimeniscitis is a pre-existing lesion, cannot be defended The processes of infiltration found in the synovial membrane are the late results of trauma and not a predisposing cause The synovial disorders which follow a meniscal injury are of mechanical nature, similar to the mechanical nature of osteo-arthritis following an unreduced congenital luxation of the hip

II *The Hemarthroses*

Review of Literature

Effusions of blood into the joint are frequent, but histological studies of the synovial membrane in effusions of blood are rare Only one clinical observation, that made by Franceschini in 1929, has been found He made histological sections from a fragment of human synovial membrane, removed in the course of a surgical procedure from a patient with a simple hemarthrosis

From an experimental viewpoint, if we omit some early observations made by Riedel, Jaffe, and Seeliger, who did not study the synovial membrane but rather the coagulation of blood in the joints, only one paper, that published by Key in 1929, actually considers this subject Under the title of "Experimental Arthritis", he studied the action of "mild irritants" in three series of rabbits In the first series, the animals each received a single injection of citrated rabbit blood, in the second series, each animal received seven injections of blood in a period of three weeks, in the third group, each animal received a single injection of India ink The duration of observation was twelve days

Only the first two groups will be considered here Irrespective of the number of injections, Key noticed a sudden increase of cells in the articular fluid, which disappeared progressively in twelve days In the first forty-eight hours most of the nucleated cells were

FIG 9

Fourth day after fracture of the patella, showing adipose synovial membrane (× 60) In the upper portion, two large villi enclose a collection of erythrocytes In the lower portion island of red blood cells is found in the hypertrophied The external layer (not reproduced) is normal

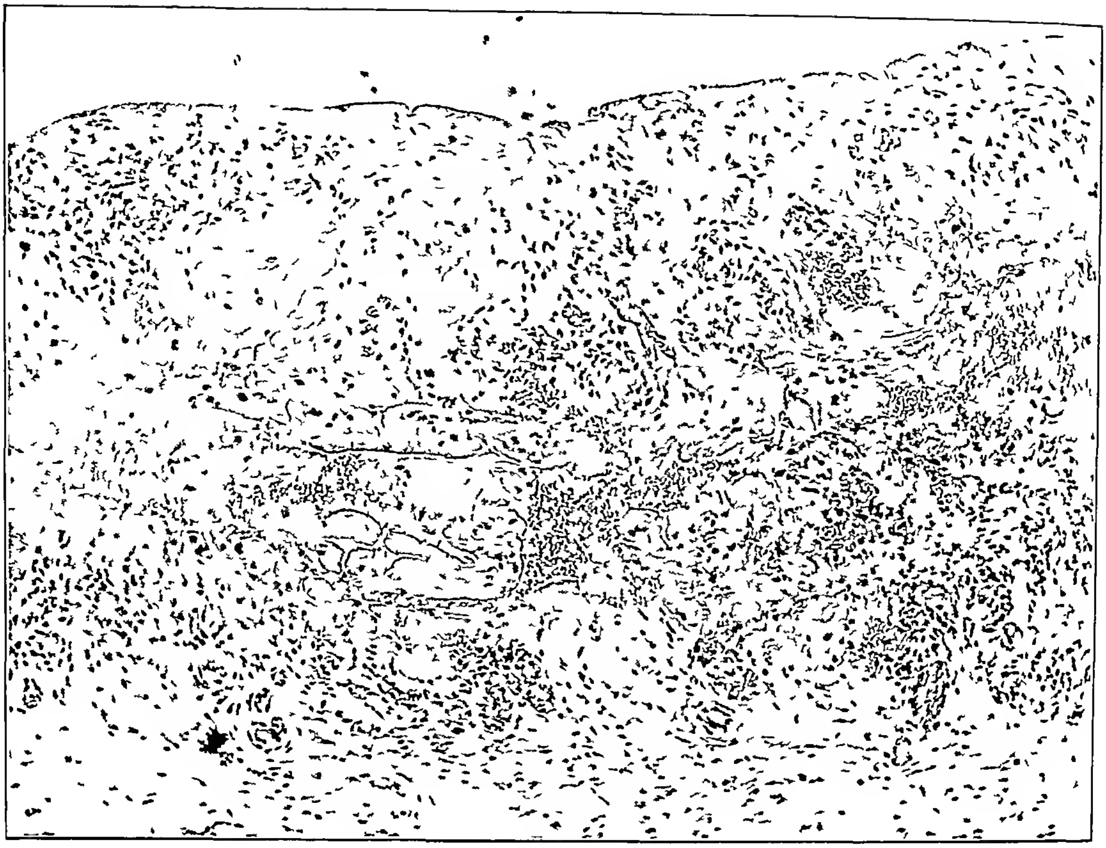

FIG 10-A

Seventh day after fracture of the patella Photomicrograph (× 75) of adipose synovial membrane represents the intima only, its thickness can be observed It differs greatly from the normal (Fig 1) The synovial fringe is flat The villi are fused Toward the lower portion there is a zone of transition with the external layer This layer (not represented here) has its usual adipose character

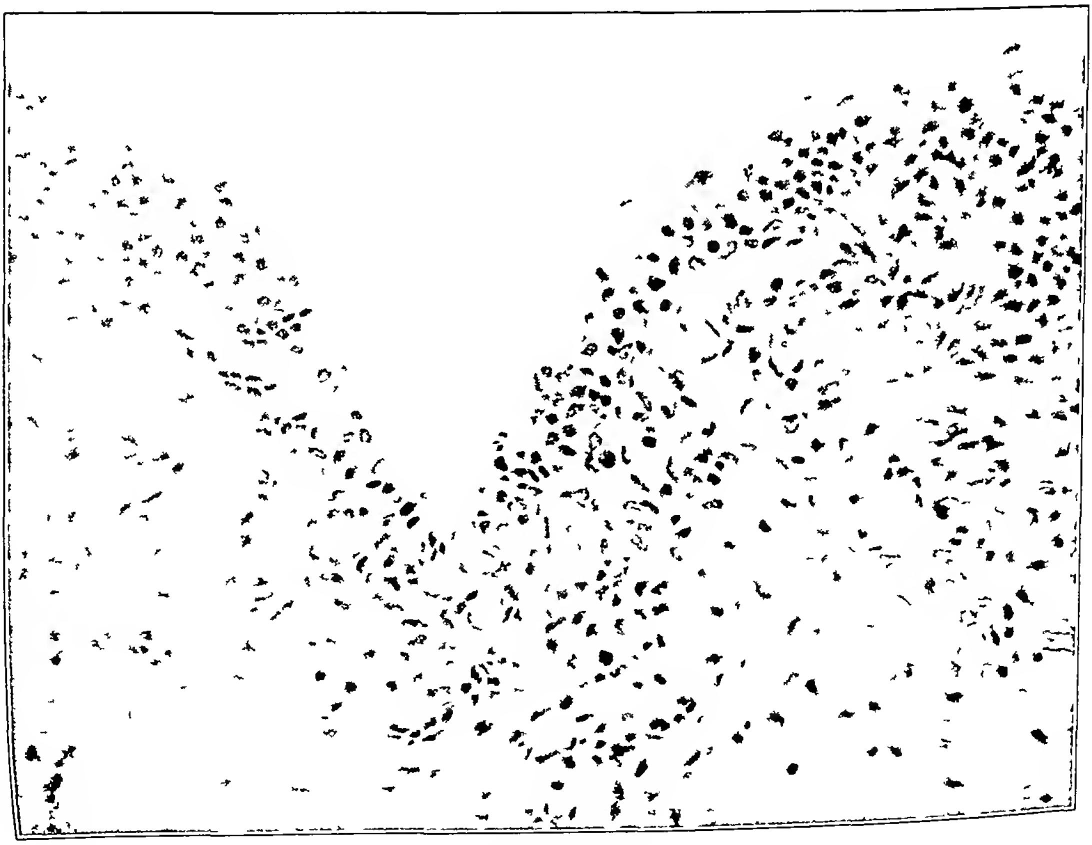

FIG 10-B

Another aspect of the same preparation (× 250) Multistratified intima is forming a pseudo-epithelium

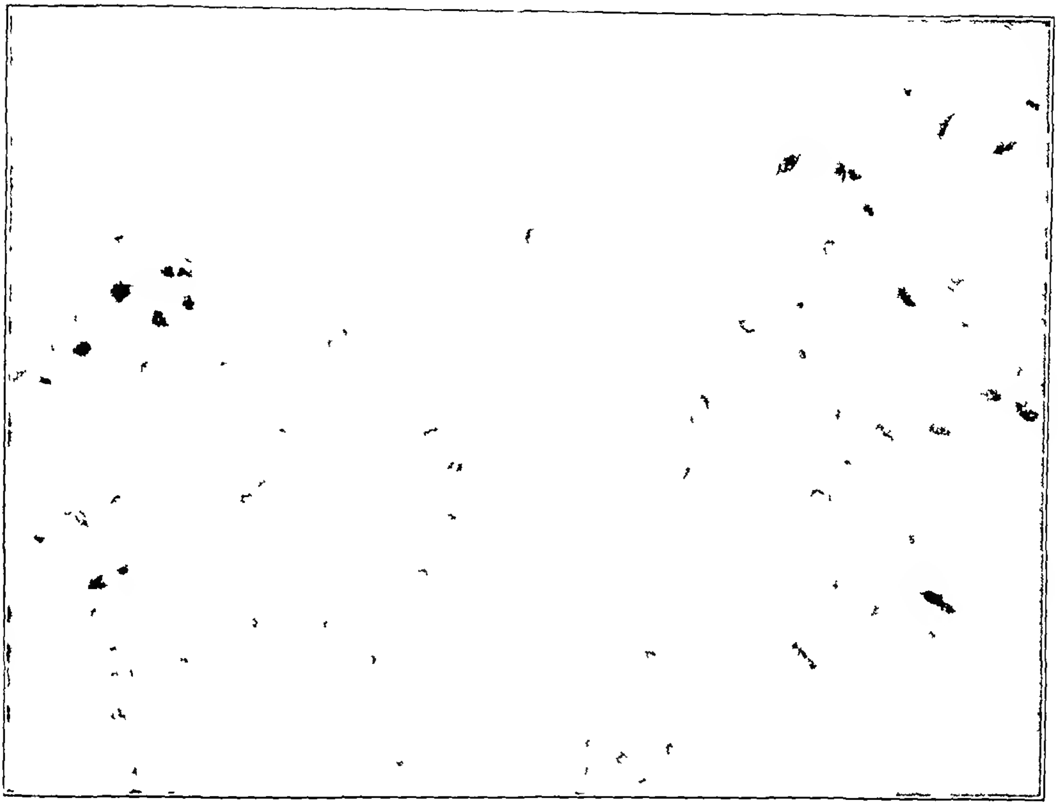

Fig. 10-C

Detail of Fig. 10-A (× 500). The histiocytes of the edge have disappeared, but deeper hypertrophic histiocytes are found. A few inflammatory cells and dilated vessels are present.

leukocytes, following this the macrophages predominated. After a single injection, section of the synovial membrane showed slight proliferation of the superficial cells and infiltration of the subsynovial layers by leukocytes and macrophages. The tissue became normal after the sixth day. Key stated that the red blood cells can leave the joint "(1) through the sheath of the tibialis anticus muscle, (2) by being carried out by the macrophages (clasmatocytes), (3) by passing between the cells of the synovial membrane, and (4) by being incorporated in the synovial membrane in instances where the blood cells are held in fibrin clots".

A few days after the seventh injection, Key noticed an increase in the number of cells in the articular layer as well as in the deep layer, also an abundance of red blood cells (in resorption), leukocytes, and macrophages. The villi were very well developed. These changes were especially important over the fat pad. Subsequently the infiltration decreased, but on the twelfth day after the last injection the synovial membrane had not returned to normal, the villi and folds persisted, the deep layer was multistratified, and the subjacent zones retained a very cellular structure with collagenous fibers. The vessels were numerous. Key commented: "Whether or not this slight fibrosis of the subsynovial tissues is permanent has not yet been determined".

Observations in Man

We have obtained pieces of the infrapatellar fat pad during the course of operations for fracture of the patella or avulsion of the tibial spine. Many biopsies were made between the fourth and the sixty-first days. The changes observed occurred only in the intima. The outer layer, on the contrary, remained fatty with only occasional fibrosis.

A. *From the first days* (Fig. 9) the villi showed an extraordinary exuberance, their ends met and adhered to each other, forming little lakes filled with red blood cells.

The intima, considerably thickened, was very rich in histiocytes, polymorpho[illegible]

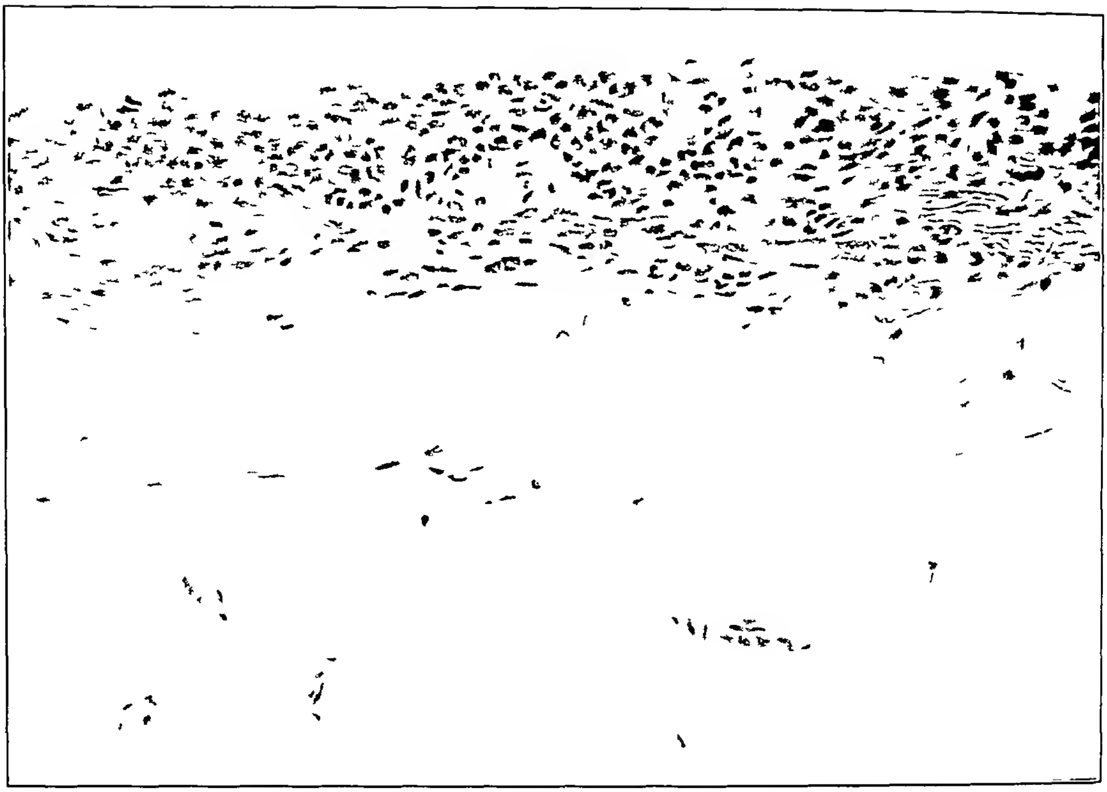

Fig 11

Adipose synovial membrane (× 250), sixty-first day after fracture of the tibial spine The articular edge is normal The intima contains intracellular pigments (not visible in the reproduction) The external layer is normal and there is no infiltration

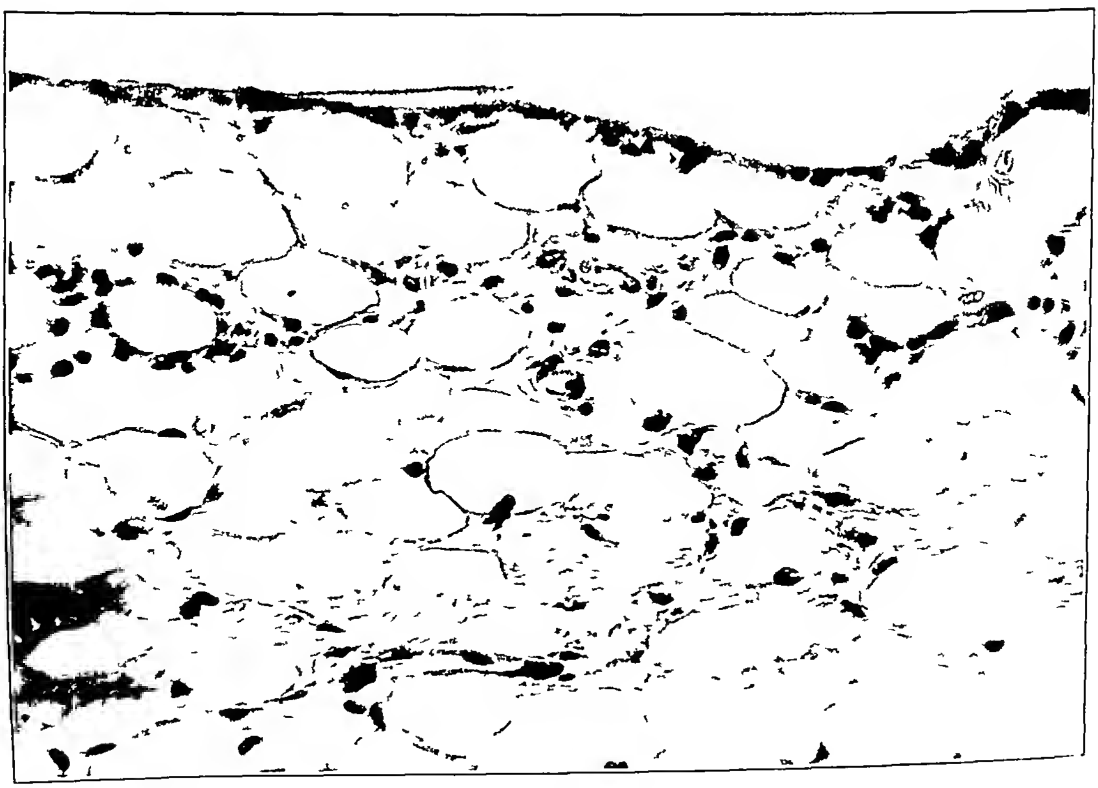

Fig 12

Ten injections, each of one cubic centimeter of blood, were given in a period of one month The rabbit was sacrificed two months after the last injection The synovial membrane (× 312) regains its adipose structure There are only a few fibrous tracts The free cells are rare and the pigments have disappeared

neutrophils, and monocytes The basal substance showed a network with wide spaces, the result of oedema The dilated vessels showed leukocyte margination

B *At the end of the first week*, there was still hypertrophy of the internal layer, in contrast to the normal aspect of the external layer The villi were fused at the tips, surrounding islets of red blood cells A smooth synovial surface reappeared (Fig 10-A)

The intima was thickened and showed a variable structure In certain areas the histiocytes, which normally represent only a single interrupted layer of cells on the surface, were increased in number (as confirmed by the presence of mitosis), and became stratified, constituting a pseudo-epithelium The cytoplasm of the most superficial cells was vacuolized, and then these cells became desquamated into the articular cavity and dissolved (Fig 10-B) In other areas the basal substance was in direct contact with the articular cavity, as if the histiocytes which covered it had completely disappeared (Fig 10-C)

The islets of red blood cells, surrounded by fused villi, showed little change and hardly any leukocyte infiltration The plasma was partly clotted, forming shreds which adhered to the denuded basal substance A discrete infiltration of polymorphonuclear neutrophils and lymphocytic cells appeared around the small vessels

The outer layer, which was typically adipose, was not infiltrated

C *At the end of the second month*, the synovial membrane had assumed an almost normal aspect The intima presented a normal articular border The histiocytes formed a multistratified layer These were intermixed in the depths with lymphocytes and plasmocytes Iron pigments could be detected inside and outside the cells, by the reaction of Perles (Fig 11)

Observations in the Animal

Under ether anaesthesia, one cubic centimeter of blood was aspirated from the ear of a rabbit into a syringe, previously treated with sodium citrate, and injected aseptically into the right knee This procedure was repeated ten times within thirty days The rabbits were sacrificed between the twelfth and the two hundred and twenty-second day

On the twelfth day the articular line showed very well developed villi and marked synovial folds The intima showed more cells than the normal side, the nuclei of fibrocytic character were also larger, with the oval form predominating The stroma, instead of being amorphous, enclosed collagenous fibrils parallel to the surface In many areas the border had indentations, as a result of the process of desquamation

The external layer had lost its typical adipose character There were still a few fat-filled spaces, but they appeared small and elongated, as if compressed by the fibro-areolar tissue which had replaced them, the fibers of this tissue were slender in the superficial portions and fasciculated in the deep layers The fibrocytes were considerably increased in number and were enlarged, their form, although variable, was often ovoid In addition, many free elements were found in the intima and in the deep layers,—histiocytes, plasmocytes, and some mononuclear cells, as well as pyknotic nuclei

Iron pigments (identified by the technique of Perles) were first visible on the surface in the intercellular spaces and histiocytes, and also deeper in the interior of the free elements Our illustrations are identical with those published by Key

At the end of the second month a very marked regression of the process was noted (Fig 12) The intima, still thickened, was formed by two layers of smaller fibrocytic nuclei The villi had become more discrete The internal border was less fringed

The external layer was mostly adipose There were only a few collagenous collections, mostly on the surface The histiocytes had regained normal size and did not contain any iron pigments, as verified by Perles' technique Practically no free red blood cells or mononuclear cells were present, but a few plasmocytes and pyknotic cells

By the end of the sixth month the findings had become normal The adipose synovial membrane of the experimental right side and that of the left side were identical and normal

Conclusions

Effusion of blood into a joint produces immediate, very intense proliferative reactions in the synovial membrane The processes take place almost exclusively in the intima, but the changes are only temporary and regress rapidly The synovial membrane gradually becomes normal, and no indication of the process remains

This experimental study permits an answer to the question of Key The fibrosis is temporary From a practical point, an effusion of blood into a joint is an incident without future repercussions In the normal subject (we did not consider the complex problem of hemophilia), hemarthrosis does not lead to chronic arthritis

We believe that aspiration of traumatic hemarthroses or removal of clots in the process of osteosynthesis of the patella is still indicated It is done only to accelerate the normal process of healing, and not to avoid definitive lesions We must also know that the blood which accumulates in a joint in the course of an arthroplasty or capsular repair is not directly responsible for possible future disturbances such as recurrence of ankylosis, stiffness, or arthritis

III *Chronic Hypertrophic Villous Arthritis*

Review of the Literature

The French surgeons in the beginning of this century had foreseen the therapeutic possibilities of synovectomy for villous arthritis of the knee joint, Mignon and Lucas-Championnière prepared precise clinical and histological descriptions After the first descriptions, however, the condition was neglected on the Continent

The credit for reviving and continuing the subject belongs to the American school (Jones, Steindler, Swett, Speed, Henderson, and many others since 1924) and later to the German school (Payr, Burckhardt, and Mandl)

FIG 13-A

Synovial villous hypertrophic arthritis in a man fifty-two years old The adipose synovial membrane (× 22 5) is replaced by a fibro-areolar membrane with numerous villi A fibrous layer is seen in the lower right portion, many nodules are visible

FIG 13-B

FIG 13-C

Fig 13-B Detail of Fig 13-A (× 175) shows large oval nodule, consisting mostly of mononuclear cells, without a trace of the basal substance

Fig 13-C Detail of Fig 13-A (× 175) shows (1) internal layer with deeply stained nuclei and desquamation of the edge, and (2) fibro-areolar layer, very lacunar, having vessels engorged with erythrocytes, fibrocytes, and large disseminated macrophages, there is finally an enormous nodule

Fig 13-D Detail of Fig 13-C (× 438) shows migrating cells, the majority participating in the formation of a nodule are plasmocytes

FIG 13-D

A good explanation of the pathogenesis of chronic villous hypertrophic arthritis has not been made The traditional means of research, consisting of microbiological and histological investigations, have not been productive The studies of Klinge and his school may, however, help in understanding the problem Klinge considered rheumatism to be a disease of mesenchymal tissue Its specific histological manifestations consist of two elements the first is degenerative,—the fibrinoid transformation of the basal substance of the connective tissue, which becomes waxy, strongly refractive, and acellular, the intrafascicular tissue is oedematous

The second stage is proliferative,—namely, an increase in the number of mesenchymal cells, which invade the waxy substance, form little groups, and organize in nodules or granulomata The blood cells (polymorphonuclear neutrophils, lymphocytes, and eosinophils) are variable in number Plasmocytes are frequently present

This conception of Klinge was based on numerous autopsies and also on exper al

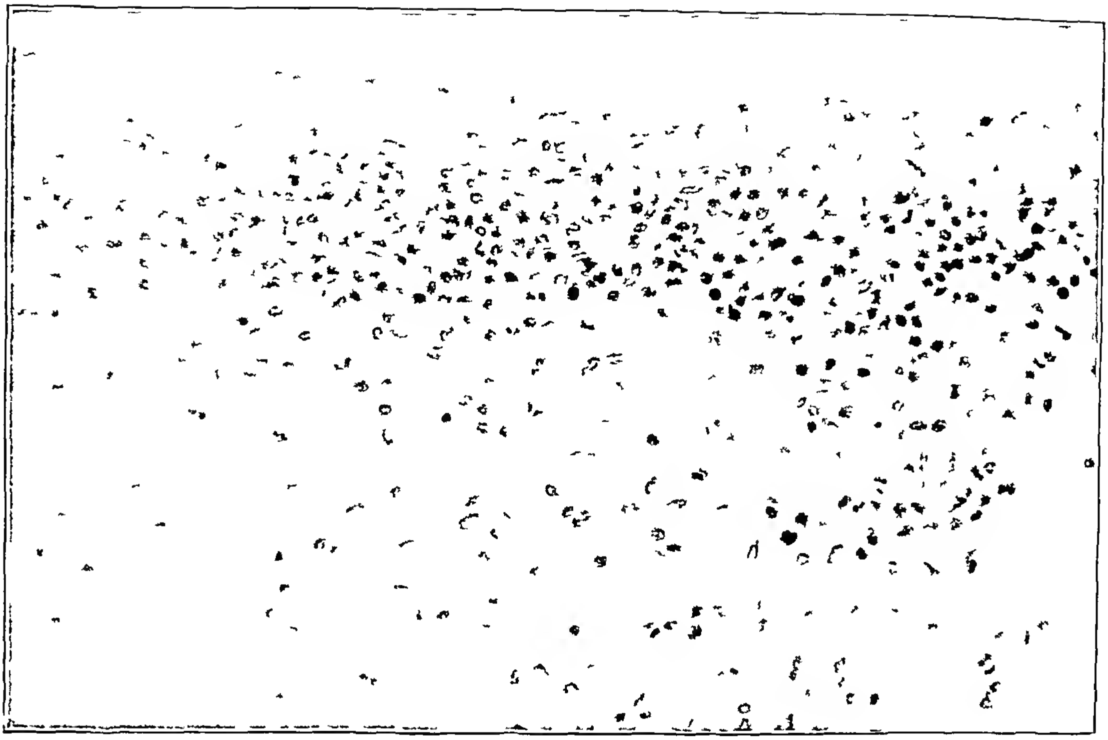

FIG 14-A

Two cubic centimeters of horse serum was injected into each flank, and, twenty-eight days later, four injections of 0 25 cubic centimeter each, into the joint The animals were sacrificed thirty-eight days after the last injection Photomicrograph (× 250) shows the intima to be hypertrophied The external layer is fibro-areolar At the border between the two zones there is strong infiltration with plasmocytes and polymorphonuclear neutrophils

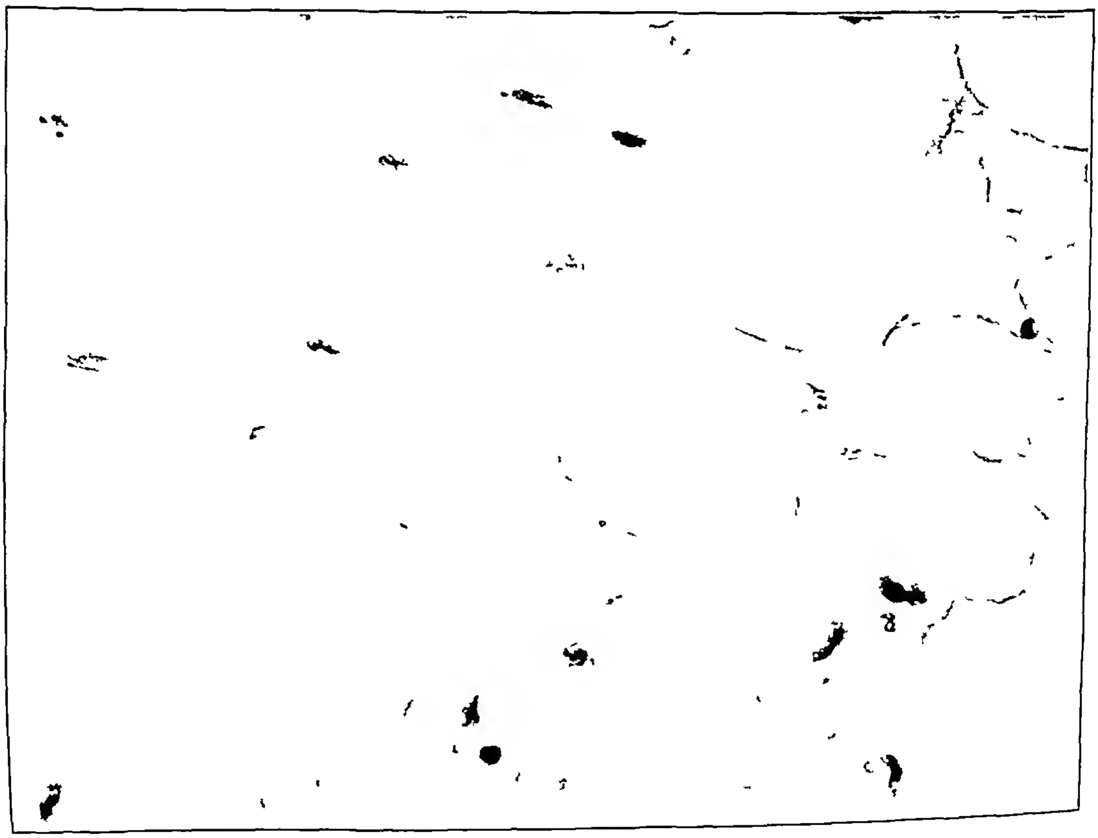

FIG 14-B

Same preparation (× 500) shows wavy degeneration of fibrous tissue, swelling and homogeneization of the poorly stained fibrils, and a few cells These areas contrast with the nodular aspect represented in Fig 14-C

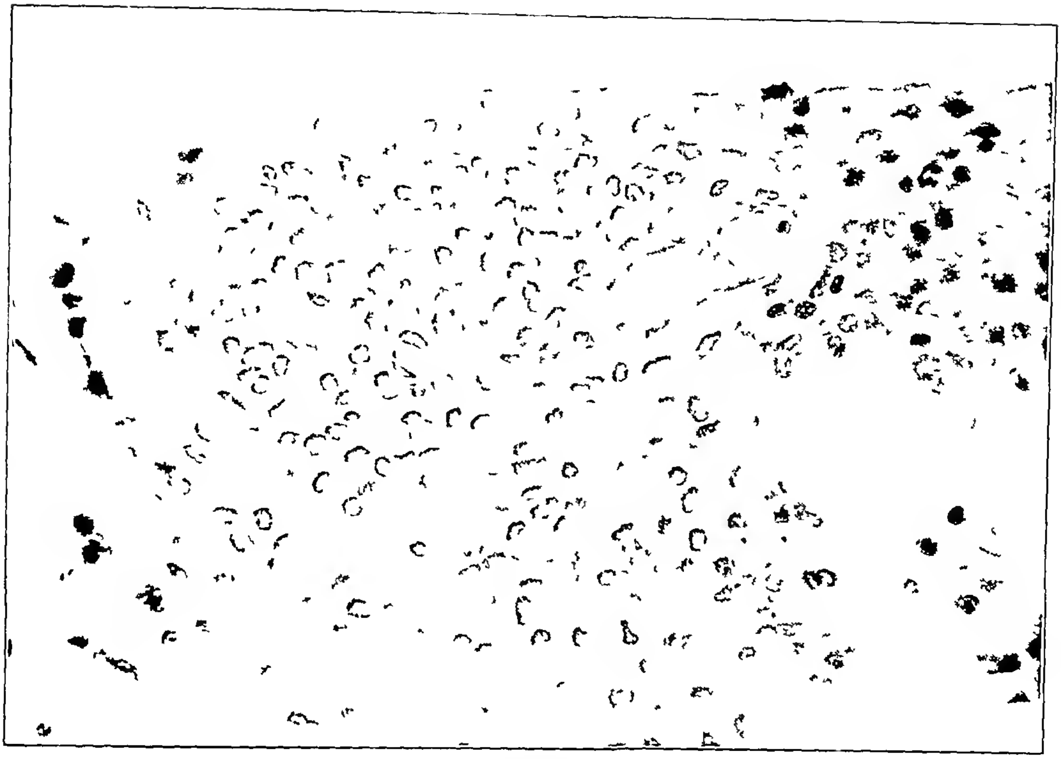

FIG 14-C
Same preparation (× 500) A true nodule of inflammatory cells

studies Animals were sensitized by albumins, such as horse serum, or by bacteria like the Streptococcus or Pneumococcus By the administration of the same antigen into the knee of the animal, anatomicopathological lesions are produced which are comparable to those observed in autopsy studies of rheumatic patients,—namely, dissolution and waxy necrosis of connective tissue, multiplication of fibrocytes, and formation of nodules

On the basis of these findings, Klinge formulated the hyperergia theory of rheumatism, consisting of application of tissue anaphylaxis to joints (phenomenon of Arthus) The rheumatic patient is a sensitized individual, hyperergic to a bacterial or other toxin, derived either directly from without or from an internal focus Under the effect of the same antigen or by action of a mechanical or climatic nature, such as cold, an allergic reaction of the mesenchymal tissues of the individual may develop

We considered that it would be of interest to verify the theory of Klinge, because the German investigator believed that, in rheumatism, the synovial changes are primary, and the osseous and cartilaginous changes are secondary Villous hypertrophic arthritis is an excellent example of synovial rheumatism

Observations in Man

In this study nine synovectomies were performed for chronic villous hypertrophic arthritis (Figs 13-A to 13-D)

We have nothing to add to the histological description of the American authorities, but a short résumé follows Two aspects were considered

At first, there was an intense cellular infiltration, involving plasmocytes, polymorphonuclear neutrophils, and mononuclears The normal synovial membrane, as would be expected, showed only a limited number of plasmocytes and no leukocytic infiltration Thus the free cells must either have become differentiated locally or have been brought in through the blood stream The cellular infiltration also involved a large number of cells of indefinite origin, which may be compared with lymphocytes or small histiocytes

Various abnormal elements were either disseminated in the subintimal region or

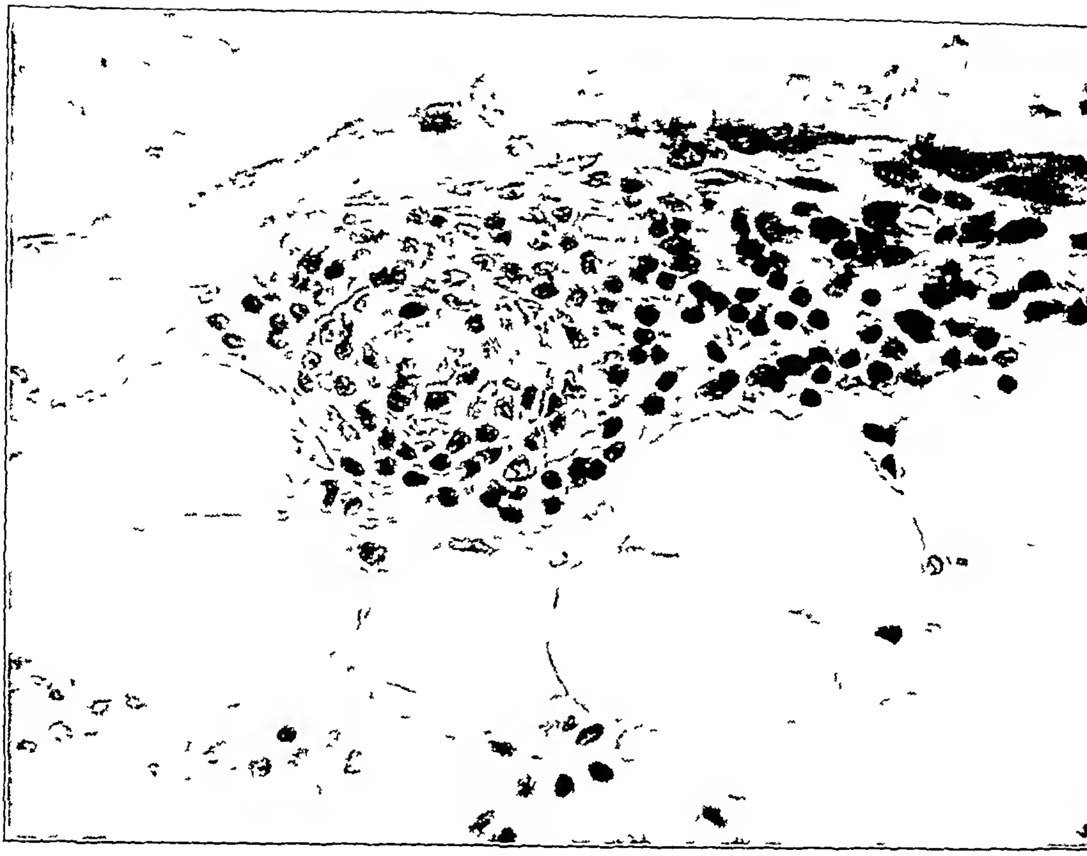

FIG 15

Two cubic centimeters of horse serum was injected into each flank, and, beginning twenty-eight days later, four injections of 0 25 cubic centimeter each, into the knee, over a period of sixteen days The animals were sacrificed 172 days after the last injection

Six months after the occurrence of the phenomenon of Arthus, the nodules, consisting of plasmocytes and histiocytes, are still present in the intima (× 500)

grouped as a nodule The most salient characteristic of the histological picture—namely, the cellular rosette either around or outside a blood vessel—was also present Around the nodule a melting of the intercellular stroma was observed,—lacunar appearance of the basal substance with disappearance of the fibrils

In the second stage, there was a hypertrophy of the synovial membrane in all its thickness, with transformation of the fat into fibrous tissue, activity of the entire villous zone, multiplication and sclerosis of the vessels, and finally oedema, probably associated with hydrarthrosis

Observations in the Animal

In this study, rabbits were sensitized by injecting 2 cubic centimeters of horse serum into each flank After an interval of one month, injections of 0 25 cubic centimeter of horse serum were made into the right knee of the animal, this procedure was repeated three or four times within ten or twelve days The animals were sacrificed between the fourteenth and the one hundred and seventy-second day after the last injection

Our findings were as follows The intima was multistratified Nuclei of the fibrocytic type were more numerous than are normally seen The striking features were their swollen appearance, irregular outline, and poorly defined chromatic contents The amorphous basal substance was thickened, poorly stained, and sometimes sent out free prolongations toward the articular cavity An increased number of plasmocytes and polymorphonuclear neutrophils were found in the intima (Fig 14-A)

The external layer had lost its adipose character A few empty vesicles could be found, but they were small in size and depressed The basal substance sometimes represented a finely reticulated tissue The collagenous fibrils appeared swollen, homogenized, and only

slightly stained, in some areas of the preparation a few degenerated cells had accumulated (Fig 14-B) These areas alternated with others which had a nodular appearance and were rich in irregular fibrocytes, histiocytes, plasmocytes, and polymorphonuclear neutrophils (Fig 14-C) The vessels were surrounded with rosettes of round histiocytes, plasmocytes, rare mononuclears, and pyknotic nuclei

This histological appearance reached its maximum definition toward the second month If afterward the signs of tissue activity decreased, they still had persisted for a long time, because six months after the last injection traces were still present (Fig 15) In these experiments the left knee which was not injected, was always examined and found to be normal (Fig 2)

We also carried out the following control experiments

1 Preparatory injections were made into the flanks without secondary injections into the knee

2 Horse serum was injected into the joint of an animal without preliminary preparatory injections The phenomenon of Arthus was never obtained in either of these experiments

Conclusions

The histological picture of chronic villous arthritis is so well reproduced in experimental allergic arthritis that we are inclined to admit the identity of the mechanism It is a reaction comparable to the phenomenon of Arthus, but obtained in a joint These characteristics are

1 Waxy transformation of some areas of the basal substance

2 Important infiltration of the two layers of the synovial membrane by cells which are usually infrequent,—plasmocytes, polymorphonuclear neutrophils, and monocytes These elements are either diffuse or well grouped and, when associated with fibrocytes, resemble the nodule of Klinge

3 Signs of connective-tissue activity, including formation of villi, desquamation, cellular density of the intima, replacement of adipose tissue by fibrous tissue, and multiplication of vessels

COMPARISON OF VARIOUS REACTIONS OF THE SYNOVIAL MEMBRANE

The changes observed in man are comparable with the reactions produced in animals Three groups of facts should be considered

By *synovial activity* we mean

Increase in number and importance of folds and villi

Irregularity of the free border and desquamation, the cells and basal substance "fall" into the joint cavity

Multistratification of the intima

Generalized proliferation of connective-tissue cells

Swollen appearance of cells

Hypervascularization

By *fibrosis* we mean

Fibrillation of the basal substance of the intima

Disappearance of the adipose vesicles of the external layer and appearance of collagen bands

Sclerosis of the walls of the vessels

By *infiltration* we mean

Multiplication of free cells, which normally are rare

Appearance of new circulating cells

With these definitions in mind, we are able to present a brief picture of the principal pathological changes observed in meniscal tears, effusions of blood and synovial arthritis

1 *Meniscal Tears*

(a) Synovial activity is marked at the onset, it subsides after six months

(b) Fibrosis is the predominant element

(c) Infiltration is usually absent, in certain very old or complicated cases it may be present, but in a discrete form

The evolution is continuous and progressive

2 *Effusions of Blood*

(a) Synovial activity is immediate, intense, and is limited to the intima

(b) There is no fibrosis

(c) The infiltration of the intima is acute polymorphonuclears, especially mononuclears, and pigment cells

The evolution is of short duration, and the synovial membrane becomes normal

3 *Synovial Arthritis*

(a) Synovial activity is intense and generalized

(b) Fibrosis is a secondary element, showing only waxy degeneration of connective tissue

(c) The infiltration is either diffuse or in the form of nodules, with predominance of plasmocytes, then monocytes, and finally polymorphonuclear neutrophils

The evolution is of long duration and is probably under the influence of further allergic responses

CONCLUSIONS

This study permits us to define the cellular behavior of the synovial membrane to various irritants In meniscal tears it is of mechanical nature, in hemarthroses it is of chemical nature (endogenous proteins), and in villous arthritis it is of an allergic nature (phenomenon of Arthus) The histological picture of each appears so different and so characteristic that it has a certain value in pathogenic research of a chronic affliction of the knee We believe that it will be possible in the future to establish with precision, through a biopsy of the infrapatellar fat pad, the factor responsible for the origin of a morbid process

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ETIOLOGY OF CONGENITAL DISLOCATION OF THE HIP *

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Hey Groves has well expressed the present-day concept of congenital dislocation of the hip as "a deformity which is mysterious in its origin, insidious in its course and relentless in its final crippling results". Numerous well-known theories for the development of this condition have been advanced. Extensive anatomical studies of normal foetal skeletons, and investigations of the pathological anatomy of foetal and postnatal material demonstrating true dislocations of the hip, have been reported. Genetic studies of the problem have indicated familial tendencies, with even a strong suggestion of a dominant Mendelian trait. Anthropological studies and knowledge of comparative anatomy have been utilized.

In general, two main theories for the etiology of congenital dislocation of the hip have predominated for many years. Throughout the literature, the main contentions for the various theories are based upon two assumptions,— one that the lesion is the result of a primary germinal fault, the other, that it is due to a defect of development of environmental origin. Recent experimental embryological work tends to show that many lesions, considered the result of a germinal defect, can be produced by environmental changes.

Although exponents of the mechanical theory can present convincing anatomical evidence to support their claim, few authorities accept this theory. The cumulative evidence of sex characteristics, hereditary factors, and geographical and racial incidence, the increasing recognition of an associated hip dysplasia on the so-called normal side, and the frequent occurrence of associated deformities have led to the more popular hypothesis of a primary developmental fault.

The most commonly accepted theory of developmental abnormality is a primary failure of proper formation of the acetabulum, particularly a germinal failure of development of the posterior superior buttress of the ilium. Murk Jansen, Bruce, Morrison, Hey Groves, Fairbank, and many others, including the present-day followers of the concept of primary acetabular dysplasia as emphasized by Faber and Hart, have believed that the flat socket is the primary developmental fault.

It is difficult to see how an observer, unless influenced by the weight of pre-existing statements and concepts, can authoritatively state a hypothesis as an accepted fact. The author denies dogmatically, for example, that there is scientific evidence of a primary genetic developmental fault of the posterior superior portion of the acetabulum. He does not refute the existence of such a lesion, but contends that no satisfactory evidence has been submitted that this lesion is the primary developmental fault. Similarly, several other authors have stated that, in the mechanism of development of congenital dislocation of the hip, although the acetabulum is defective, the head is within the socket with the hip in the typical intra-uterine position of flexion. On extension of the lower extremity after birth, dislocation may occur suddenly, or gradual displacement may result. With what proof is this statement of the time occurrence for congenital dislocation of the hip made?

There is on record, it is true, evidence of congenital dislocation in a five-month foetus. The teratological dislocation is undoubtedly prenatal in origin, and another type, to be discussed, also occurred prenatally. Rather should one say that the time of occurrence of congenital dislocation of the hip is not known, because of inadequate investigation in early life. Certainly Putti, stressing the features of early diagnosis by his triad of criteria, has demonstrated the possibility of recognizing preluxation of the hip at a much earlier age, by a process of education of the public and the doctor to look early for this abnormality.

* Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 30, 1947.

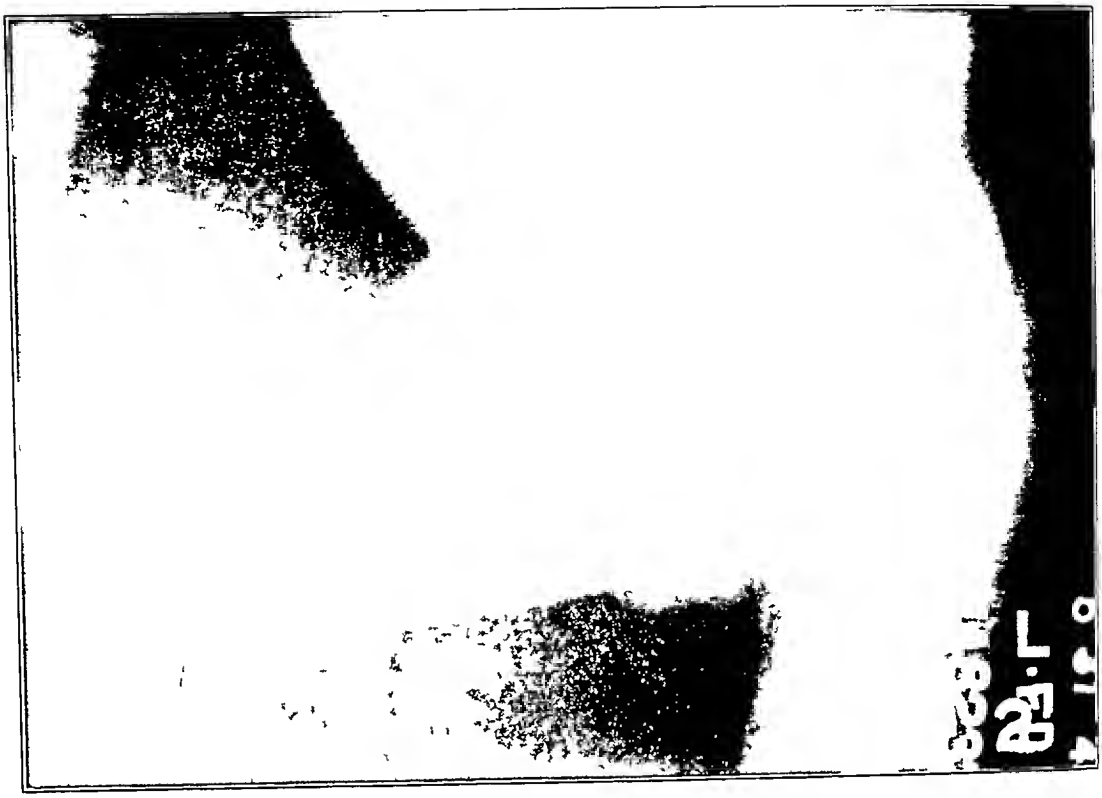

Fig 1

Child with abduction and flexion of right lower extremity and hyperextension of the tibia on the femur, associated with dislocation of the left hip, probably the result of the dangerous position of adduction in production of pathological dislocation A roentgenogram of the mother's pelvis, one week before delivery, showed this same deformity *in utero*

It is time for us to investigate the etiology of dislocation of the hip, free from prejudice, assembling the facts without bias Conjecture should not be presented as fact

MECHANICAL FACTORS

Mechanical factors producing dislocation of the hip have been recognized in the postnatal period The position of flexion and adduction has been demonstrated in a number of clinics, including our own, as a dangerous position in hip-joint infection, leading to pathological dislocation Certain isolated cases of congenital dislocation of the hip have been reported, which have a similar mechanical malposition, known to be a potential cause of dislocation of the hip in postnatal life Tubby stated that Tridon had reported 121 cases of congenital dislocation of the knee, in twenty of which congenital dislocation of the hip occurred due to intra-uterine mechanical causes

Through the courtesy of the Ford Hospital, the author has had the opportunity to see such a case of congenital dislocation of the knee, associated with abduction of the hip on the same side (Fig 1) The opposite hip was adducted and dislocated The foetal movements were said to be unusual, being felt in only one place above the left iliac crest Roentgenograms of the mother, taken a week before delivery, clearly demonstrated the fixed deformity of the limbs *in utero* Such an isolated case is, however, not a substantiation of the mechanical theory for dislocation of the hip except in unusual circumstances

The mechanical concept of Le Damany and Dega seems plausible, but does not explain adequately the environmental, genetic, and racial features

There are many factors opposed to the concept of a primary developmental defect of the acetabulum as the cause for dislocation of the hip Numerous unsubstantiated explanations for this fault have been offered, such as early arrest of the Y cartilage and more recently, a primary developmental failure of the posterior superior buttress of the acetabulum

An intensive review of the etiology, in light of recent methods of embryological experimentation, is necessary. The information available at the present time is inadequate, but may show the possibilities for future study.

GENETIC STUDY

The approach to the problem of inheritance factors in congenital dislocation of the hip is very difficult. Patten has stated that the basic problem of the interplay of heredity and environment, although "both are involved in the causation of anomalous development", makes generalizations unsure as to their relative importance. Warkany and his associates found that feeding defective diets to normal breeding rats produced offspring with skeletal defects. Such findings, which hitherto had always been regarded as the result of a primary intrinsic fault, show the importance of extrinsic or environmental factors that may simulate a hereditary intrinsic fault. Patten stated that Stockard had produced experimental evidence "that different disturbances applied at the same phase of development would tend to produce the same defects, whereas the same disturbing factor applied at different phases of development produced different defects".

Hart, in an excellent paper on primary genetic dysplasia of the hip, quoted from Faber's work and his own to show that there are latent carriers of the gene for hip dysplasia. A true genetic history cannot be gained from a study limited to hip dislocation. Hart stated that hip dysplasia is due to a dominant gene. An incidence of about 20 per cent of genetic occurrence in families has been reported by many authors. According to Hart, Faber demonstrated that dysplasia of the hip joint was three times as frequent as was classical dislocation. Therefore, a search for dysplasia of the hip shows a much higher incidence, as indicated by di Piampero's studies.

Patten has pointed out that enough data for genetic studies in man have not yet been accumulated to be definitely informative, that specific mating is not feasible, and that the heterozygous human germ plasm makes definite conclusions as to the importance of intrinsic and extrinsic factors most difficult.

PRINCIPLES OF DEVELOPMENT

We are indebted to Weiss for the following observations. Experimental embryology has added definitely to the knowledge of embryonic development. It seems to be established that there is, in general, almost a predestined mosaic pattern for development which, if carried out in a normal environment, will result in a normal development peculiar to the species. Each species, as well as each system of the species, has its own peculiar growth pattern. This growth pattern, inherently designed by intrinsic factors, is dependent, however, upon the environmental conditions, the *extrinsic factors*, under which it proceeds. Temperature, nutrition, and other environmental factors may accelerate or delay the normal growth rate. The predisposition for normal growth is the growth potential which may be interfered with by factors indispensable for its realization; these so-called "growth circumstantials", however, are not responsible for the characteristics of growth. The growth rate may be normal or abnormal. Embryonic growth of a part advances unevenly. Each system has its own time period, influenced and controlled to some extent by the body as a whole. Interference with growth of a part will produce far more abnormality during a phase of rapid growth than during a quiet phase. It has been shown that abnormalities in development do not depend upon the nature of the exciting factor so much as upon the time period of the disturbance of normal growth.

Perfect timing for the development of the constituent parts is essential. This is well demonstrated elsewhere embryologically in the failure of proper timing in the development of the heart valves, producing congenital heart lesions, and similarly in the time orderliness of the development of the eye. Patten has discussed the development of rachischisis of the spine from faulty timing in growth.

Parts of a joint can develop typically, however, even though they are not in continuity. Experiments in limb-bud transplantation have demonstrated that a typical socket is developed by the shoulder girdle when no humerus is present, and, similarly, that a typical head of the humerus has developed in the absence of a shoulder socket. Nevertheless, the continued embryonic growth of this intrinsically designed head or socket would alter without the environmental factors present to guide its intrinsic design. It is important to remember the fourth dimension, time, in this dynamic growth,—not what has happened but what will occur as a result of environmental change.

Murray made the following statement: "Summarising, it may be said that the gross form of those kinds of elements which have been mentioned (mainly parts of the limb skeleton) is developed by self-differentiation, that is, under the direction of factors intrinsic in each developing element. These factors are not, however, sufficient for the production of a functional skeleton. In the early stages, when the development of gross form is proceeding, it is doubtless essential that extrinsic forces such as the growth pressure of other elements, etc. shall not deviate far from the normal conditions; it would be absurd to suggest that the intrinsic factors could produce a normal skeleton however unfavourable the extrinsic factors might be. In early stages the intrinsic factors are determinative, the extrinsic factors only important in providing conditions in which the intrinsic factors can act. In later stages, when the gross skeletal model is being refined and perfected, the importance of extrinsic factors increases. It is doubtless the correlation inevitably following upon development and early function in close contact that causes the two components of a joint to be so perfectly adapted to one another, and evidence has been presented which indicate that various grooves, prominences, etc., of the late embryonic skeleton are probably produced in reaction to extrinsic and presumably mechanical factors."

Hamburger and Waugh studied nerveless or poorly innervated limb buds and concluded that innervation played a minor role in the development of joint formation. Normally developed skeletal design often occurred in these transplants, in spite of isolation from the body and lack of innervation. Continued development of these abnormally placed and poorly innervated limbs is not recorded, but doubtless would be most inadequate. Hamburger and Waugh concluded that although "the primary development of the limb skeleton is thus shown to be self-differentiation to a high degree, extrinsic factors become of increasing importance in later phases of bone development". These studies all demonstrate the mosaic pattern for development, the growth potentiality is initially of great importance, but extrinsic factors may later alter the intrinsic design. Hamburger and Waugh quoted Harrison as warning against "the indiscriminate acceptance of the concept that differentiation proceeds universally from an undetermined state to one of rigid mo[...] development".

It is important to recognize that the mosaic pattern may be interrupted or altered. The prospective potency—that is, the full range of developmental performance of which a given part of the germ is capable under any conceivable circumstances—equals its prospective fate, the lineage of each part of the egg through its cell descendants into a definite portion of the adult. One must have the concept of timing,—the dynamic concept of changing structure. The tempo of operation is an important characteristic which each cell has inherited from the egg. Perhaps here the chief influence of heredity, environment, and geographic and racial characteristics is felt. An inherited alteration in the proper timing of growth of the hip system, or environmental delay or overstimulation, might well result in faulty development. To recognize the potentialities of normal or abnormal growth, the concept of the necessity for perfect timing during the various phases of growth of the hip joint must be understood.

Rotation of the Limb Bud

The evolution of posture of the pelvic limbs is characteristic for the human spec[...]

This alteration of position is a well-recognized embryological fact of great importance clinically and anatomically. It has been shown by a number of observers, particularly Bardeen and Lewis, that the limb buds in the human embryo undergo a rotation phenomenon. Bailey and Miller stated that the lower limb bud appears at the end of the third week as a small rounded protuberance on the lateral body wall, opposite the sacral flexure. During the fourth week, elongation occurs and the transverse constriction, separating the proximal from the distal portion, develops. During the sixth week, the limb bud is marked off by a bend for the knee.

As the limb buds first elongate, their long axes lie nearly parallel with the long axis of the body. Later they are directed ventrally, nearly at right angles to the body axis. The tibial margins are turned toward the head. To acquire positions relative to the body as found in postnatal life, the extremities must undergo further changes. These consist of torsion around their bony axes and rotation through an angle of 90 degrees. The right lower extremity twists to the left. At the same time both extremities swing backward through an angle of 90 degrees, so that they lie parallel with the long axis of the body.

It is clear from the illustrations of selected embryos (from 8 millimeters to 58 millimeters) that the alteration of position of the limb buds starts prior to the separation of the component parts of the hip joint. Even the 15-millimeter embryo shows lessened abduction of the limb bud. Doubtless this alteration is influenced by growth of the embryo in length. It seems obvious that this postural change of the limb bud prior to motion in the hip joint may be a definite factor in the production of the inclination of the neck of the femur, characteristic of the human species. Most of the postural change of the limb buds develops, however, after the separation of the head of the femur from the acetabulum, which appears usually after the 30-millimeter stage of the foetus.

Thus the hip joint is peculiar in its development. Originating in a lateral abducted position to the pelvis and acetabular anlage, the head of the femur and the shaft must adduct to a position parallel with the long axis of the trunk, practically 90 degrees, and must rotate internally approximately 90 degrees at the hip joint to allow the patella and leg to face forward. Much of this rotation occurs during the third month, but is not complete even after birth. Some degree of retention of the foetal position of external rotation is commonly seen months after birth, even continuing at times until adolescence.

Not only are adaptive changes in the acetabulum and the upper end of the femur necessitated by this rotation phenomenon, but there is development of the oblique position of the acetabulum to the sagittal plane. An increase in growth of the posterior portion of the pelvis in proportion to the extent of growth of the pubic portion is a well-recognized anatomical fact. Thus the position of the acetabulum is developed with a forward and a downward inclination. Steindler gives a statistical report of 40 degrees of forward inclination and 60 degrees of downward inclination. In a recent study from our clinic by Donovan and Campbell on the adult pelvis, the angle of forward inclination was 30 degrees and the angle of downward inclination was 60 degrees.

Dega, in a review of 100 foetal skeletons, showed the angle of forward inclination of the acetabulum to be 29.5 degrees. The downward inclination in relation to the transverse plane was 62.8 degrees. Dega showed that the downward inclination increased gradually, paralleling the increase in anteversion of the neck of the femur. The decrease in the forward inclination of the pelvis, however, did not begin until the eighth or ninth foetal month.

Le Damany pointed out that the human foetus has undergone three deformities at the time of birth which are not found in animals. First, he referred to the pelvis deformed by tilting of the iliac bone on the sacrum with enlargement of the pelvisacral angle; second, to obliquity of the acetabulum; and, third, to anteversion of the head and neck of the femur, associated with torsion of the femur. He argued that, if the sum of the obliquity of the acetabulum and the anteversion of the neck is greater than 60 degrees, dislocation occurs.

The author [1,2] has pointed out that the characteristic posture of the limbs in arthro-gryposis multiplex congenita closely approximates the early foetal position of the limb buds. We attribute this to failure of rotation of the limb buds, due to the absence of muscle function in the extremities, which is characteristic of the syndrome. This empha-sizes the importance of the foetal muscles in the production of torsion and anteversion, as with extensive muscle involvement, neither torsion nor anteversion is evident if the limbs are in the characteristic posture. In the instances of this syndrome associated with dislo-cation of the hip, the response to abnormal position of the constituent parts of the hip joint is beautifully illustrated by the case of R. L. M. [2] Operative inspection demonstrated that the head, having laid above the acetabulum anteriorly, had produced a marked notch in the ilium, which was undoubtedly the result of diminished growth from pressure. The ilium above the displaced head of the femur grew forward normally. The head was then pointing directly into the pelvis and into the iliacus.

Lack of rotation of the limb bud, the retention of the foetal position of the limb, and the position of abduction in these cases may have levered the head forward and left it displaced in a subspinous position. The malposition of the head produced a failure of development of the cartilaginous anlage for that portion of the anterior margin of the ilium pressed upon by the head of the femur. This demonstrates environmental restraint of growth. McCarroll and Crego have reported a similar defect in the anterior margin of the ilium in their cases of anterior dislocation of the hip.

This is an adaptive environmental change, not a primary developmental fault. It is, however, analogous to the maldevelopment of the posterior superior surface of the acetabu-lum, regarded by many as the resultant of a primary developmental fault.

Dega, in his careful study of the skeletal anatomy of 200 foetal hips, noted marked similarity in the measurements of the head and acetabulum. This, he felt, demonstrated the reciprocal relationship between the two structures. He pointed out, however, that perfect adaptation of the component parts was present only in one position,—the intra-uterine position of flexion. He was of the opinion that dislocation of the hip was definitely a consequence of a bad adaptation of the human species to an upright posture. Regardless of this opinion, the anatomical fact remains that the shape of the socket and the head were congruous in their development when normal, denoting that, in the absence of an envi-ronmental fault, such a development is the mosaic pattern for the hip joint. Perfect forma-tion of the joint for this reciprocal development requires perfect adaptation and timing for the altered positions of the components of the hip joint during rotation of the limb bud.

EMBRYOLOGICAL SECTIONS

Through the courtesy of the Department of Anatomy, we have selected a few trans-verse sections of the developing hip joints of embryos, varying from 8 to 58 millimeters. These sections illustrate the findings which were so well presented by Luther Strayer. The author has utilized Strayer's work freely in interpreting these sections.

In a transverse section through the lower limb buds in an 8.5-millimeter embryo (Fig. 2), the neural tube was at the top. The limb bud was in the finlike position, pro-truding laterally, and consisted of a mass of undifferentiated mesenchyme. From this period on, the limb bud develops as an entity, only the nerves and vessels growing in from the trunk. There is no definite evidence of the trunk sending other constituents to the limb bud.

As the embryo elongates to 14.8 millimeters, the limb bud develops further, deve-loping ventrally and less laterally (Fig. 3-A). The constriction and bend for the knee become apparent. The mesenchyme shapes itself into the outlines of the blastemal innominate, and the dumbbell-shaped femur is outlined (Fig. 3-B). A hint as to the future site of the hip joint may be observed at the dense accumulation of mesenchyme. The abducted flexion of the thigh and the external rotation of the limb bud may be noted at this sta-tion. Nerve tissue is present in the popliteal space.

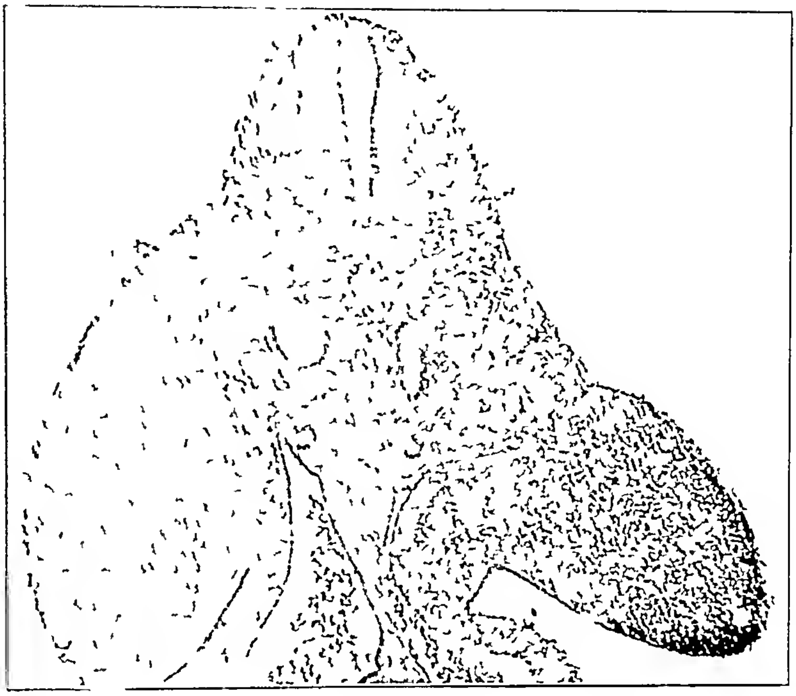

FIG. 2

Transverse section through lower limb buds in an 8.5-millimeter embryo shows neural tube at the top.

At 25 millimeters there is further differentiation of the hip joints. The innominate structures are clearly outlined; there is a clearly differentiated acetabular development and a rounded femoral head. Undifferentiated mesenchymal tissue is still present between the outlines of the head and acetabulum, connecting the two structures which are not yet separated. The capsular structures are forming and there is early evidence of the development of the glenoidal labrum. Further rotation of the limb bud is obvious.

A section at 28 millimeters shows more clearly the cartilaginous nature of the innominate bone and the femur, and the retention of numerous cells about the head of the femur (Fig. 4). Mesenchymal tissue, still undifferentiated, fills the space between the acetabulum and the head of the femur. An early appearance of the glenoidal labrum is suggested in the increased density of the mesenchymal tissue above the head of the femur. The two components of the sciatic nerve are present just medial to the tip of the trochanter. The external rotator muscles are well defined. The amount of abduction of the hip has diminished to about 60 degrees. Inasmuch as there is no separation of the head of the femur from the acetabulum, this must be the method for developing the angle of inclination of the neck of the femur.

As seen in the 33-millimeter embryo, the formation of the joint space is completely differentiated throughout, but clearly separate in the upper third. The ligamentum teres makes its appearance at this time, and the glenoidal labrum has extensive prolongation over the head of the femur. The capsule has separated from the glenoidal labrum and is attached above it; the articular surface of the acetabulum is continuous with the articular margin of the glenoidal labrum. The differentiation of muscle structures and nerves is clearly seen. Photographs of the embryo show the continued rotation of the limb buds (Figs. 5-A and 5-B).

In a section of a 53-millimeter female, taken at the level of the greater trochanter (Fig. 6), the ligamentum teres, the transverse acetabular ligament, and the glenoidal labrum are shown. At this stage the ligamentum teres is attached to the head, the capsule is attached above the glenoidal labrum.

In a 58-millimeter male, there was marked lessening of the abduction, and the ligamentum teres and its vascularity could be seen. The importance of the glenoidal labrum as a "sucker" ligament was obvious in the deepening of the socket. Beginning ossification of the ilium was taking place.

Comment

These sections reveal the development of the limb bud, and particularly of all the elements of the hip joint from the undifferentiated mesenchymal tissue to a structure

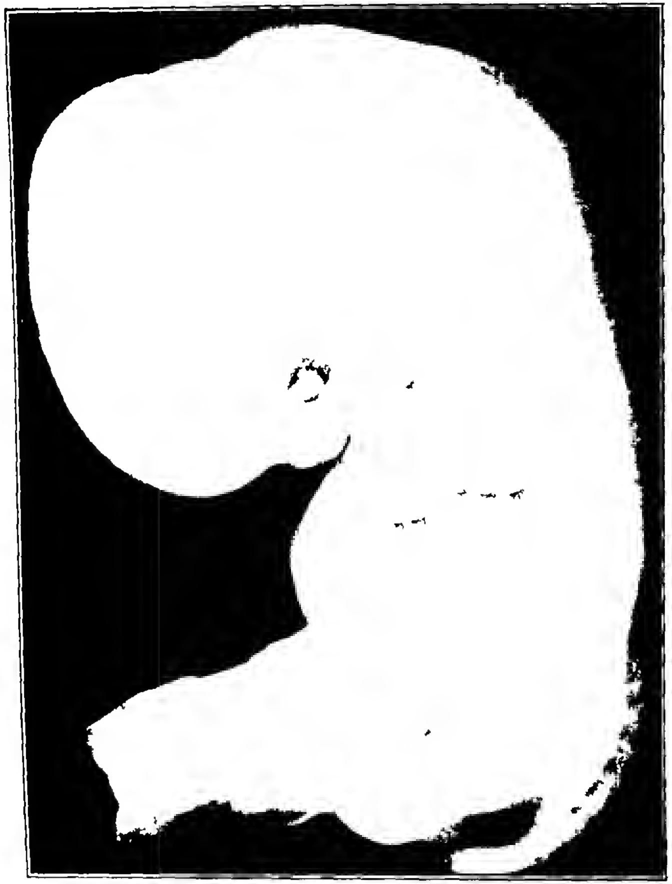

Fig 3-A

Fig 3-B

Fig 3-A 14 8-millimeter embryo, demonstrating the alteration of position of the limb buds with the development of the knee bend and more central turning of the limb The angle of inclination of the neck is probably formed by this bending, prior to separation of the head of the femur from the acetabulum

Fig 3-B 14 8-millimeter embryo, after section Outline of femur can be seen

FIG 4
Section of 28-millimeter embryo shows cartilaginous nature of innominate bone and femur

that closely resembles the developed hip joint with all of its recognizable adult characteristics in the short period of growth from an 8 5-millimeter embryo to a 53-millimeter female foetus The hip-joint space was first noted in the 33-millimeter embryo in this series Strayer pointed out that, in six embryos between 36 and 45 millimeters which he examined, development of the joint space was well under way He said it had been suggested that factors of muscle innervation and function probably have some influence on the time of opening of the joint space Early maturation of the neuromuscular mechanism might cause a joint to be opened early, while a slowly developing neuromuscular apparatus might allow the embryo to reach a greater length before this occurred This constitutes a possible determining time factor which may alter the rigid mosaic of the intrinsic design

One must be impressed by the orderly development of this undifferentiated mesenchymal mass into the predetermined structural design of the mature characteristics of the hip joint The intrinsic mosaic pattern for development in a normal environment is illustrated (Fig 7) Can there be an inherited failure of development of the posterior superior border of the acetabulum in such a developmental cycle, indicating that all of the elements of the hip joint are differentiated *in situ* from one mass of mesoderm? Such a concept seems incredible

ENVIRONMENTAL THEORY

Hereditary factors and environmental factors, such as geography and nutrition, may well alter the normal rate of growth and interfere with chronological development by delay or stimulation of growth Delay in innervation of the muscles or in rotation of the limb buds at a period of rapid growth may produce an alteration in the deepening of the socket and changes in the head and neck of the femur The adaptive variations to the stimulus of pressure and abnormal positions of the constituent parts of the hip joint,

FIG. 5-A

FIG. 5-B

Fig. 5-A. Photograph shows the continued rotation of the limb buds in a 33-millimeter embryo, with the patella still facing somewhat laterally.

Fig. 5-B. Section of 33-millimeter embryo, showing the continued rotation of the limb buds. The capsule is separated from the glenoidal labrum; the articular surface of the acetabulum is continuous with the articular margin of the glenoidal labrum. The differentiation of muscle structures

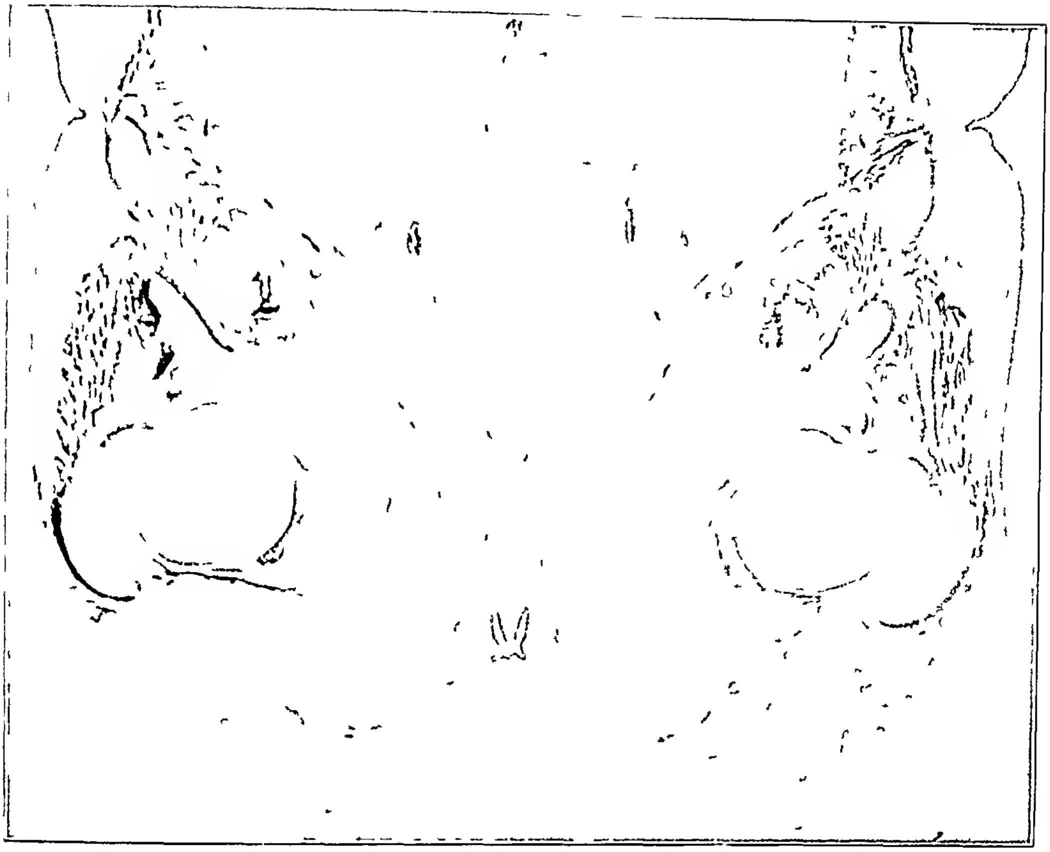

Fig. 6

Section of a 33-millimeter female embryo, taken at the level of the greater trochanter.

recognized by clinicians in the postnatal changes, can certainly occur with even more marked alterations in a shorter period of time in the early prenatal phase. Why do we accept the postnatal changes in congenital dislocation of the hip as adaptive to malposition, and yet fail to recognize the potentialities of environmental or adaptive changes *in utero?*

Can it be said in one breath, as Murk Jansen and numerous of his followers have reported, that the flat socket is primarily the developmental fault, and in the next breath that the changes in the femur are secondary adaptive changes? Is it not more reasonable to assume in a structure of component parts, such as the hip joint, conjugated from a single mass into its integral parts, that the fault lies not in a hereditary failure of one part, but in an interference in the orderly time development of reciprocal parts after the formation of the joint cavity? It seems more logical to anticipate changes from extrinsic factors in both the acetabular structures and the femur, on the basis of a secondary adaptive fault from an alteration in the normal timing of development. A delay in position, even of short duration, might well alter the normal dynamic rearrangement of the component parts, so that normal development is interfered with to the extent of reciprocal changes in the hip structures. These may well be manifested by a shallow socket, enlargement of the head to accommodate it, increased anteversion, and even subluxation. This would account logically for all of the recognized deformities noted in congenital dislocation of the hip.

The Glenoidal Labrum

It is, of course, an anatomical fact that the acetabulum and its margins are entirely cartilaginous at the time of birth. The depth of the true acetabulum is greatly increased during prenatal life by the fibrocartilaginous structure called variously the limbus, the cotyloid ligament, and the glenoidal labrum. This ligament aids in enveloping the head of

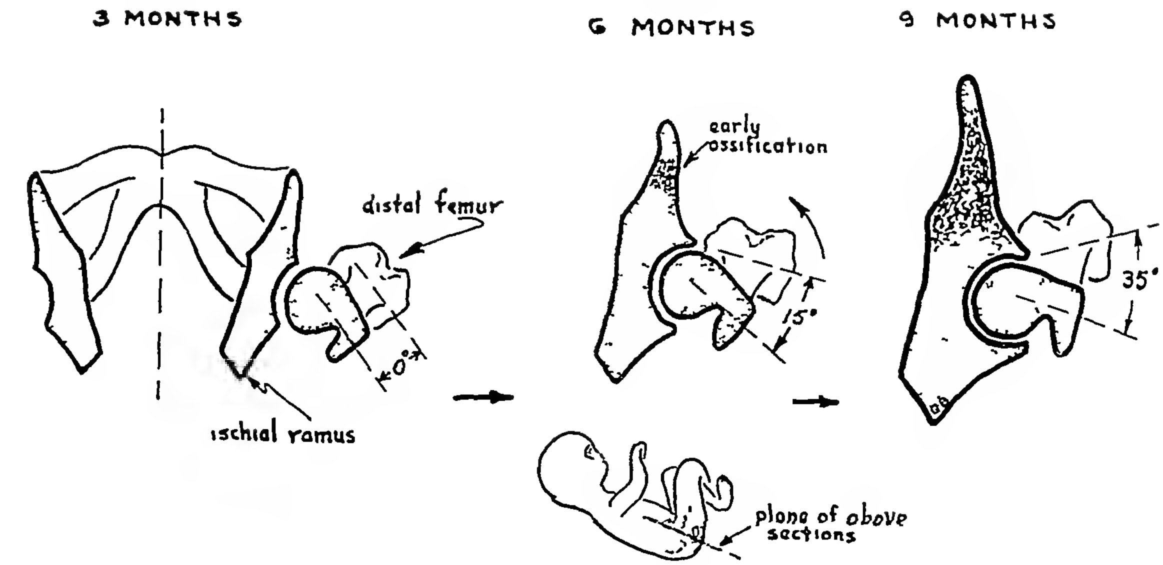

FIG 7

Development of the normal hip joint Graphic attempt to illustrate the reciprocal development of the head of the femur and the acetabulum, as the limb buds alter their lateral position to one of parallelism The torsion of the femur, the change of position of the ilium, and the increasing anterior obliquity of the acetabulum produce an increasing anteversion of the diaphyseal junction from 0 degrees at three months to 35 degrees at birth The acetabulum steadily deepens and the head, properly fitting the socket at all stages of rotation, is symmetrically developed for the socket

the femur Severin developed an excellent illustration from a roentgenogram, demonstrating the size and importance of the glenoidal labrum in the newborn, by painting with an opaque substance the dissected edge of the limbus No one has mentioned any primary deficiency of the limbus, and yet it is an early embryonic development of obvious importance in increasing the depth of the socket and thereby maintaining stability of the femoral head within the socket

Severin [27] also described how Faber demonstrated in normal hip joints, by opaque media arthrograms taken after birth, that the cartilaginous acetabulum and limbus covered at least half of the femoral head The normal head is spherical in shape

In subluxation, a term which we believe to be synonymous with dysplasia of the hip, the limbus is displaced upward, covering less of the head but still remaining above the head, which is between the limbus and the socket The head is displaced laterally, with apparent coxa valga, in Severin's illustrations This malposition is the result of anteversion and not of coxa valga, as can readily be proved by roentgenograms taken with the lower extremity in internal rotation In true dislocation, the limbus lies between the head and the acetabulum Severin stated that the head glides past the glenoidal labrum which because of its elasticity, returns to its position below the displaced head of the femur

An important report was made by di Pramperò, based on a roentgenographic study of 200 patients with unilateral dislocation, to determine the principal characteristics of the so-called healthy side Subluxation or dysplasia of the hip was found in 108 cases, subnormal hips in 41, and normal hips in only 51 cases Eighty per cent of the so called normal hips showed pathological changes Di Pramperò believed this parallelism of deformity demonstrated that the articular imperfection is not located in the hip, but in the pelvis as a whole and in the individual himself With this observation the author is in full accord

Various observers have demonstrated roentgenographic methods of determining abnormalities in the very young infant, leading to or suggesting the possibility of the *development of so-called acetabular dysplasia or* congenital dislocation of the hip The measurements, namely, Wiber's lines, the acetabular index of Kleinberg, the Y line, and Shenton's line, all tend to demonstrate Putti's triad for so-called preluxation of the hip This consists in

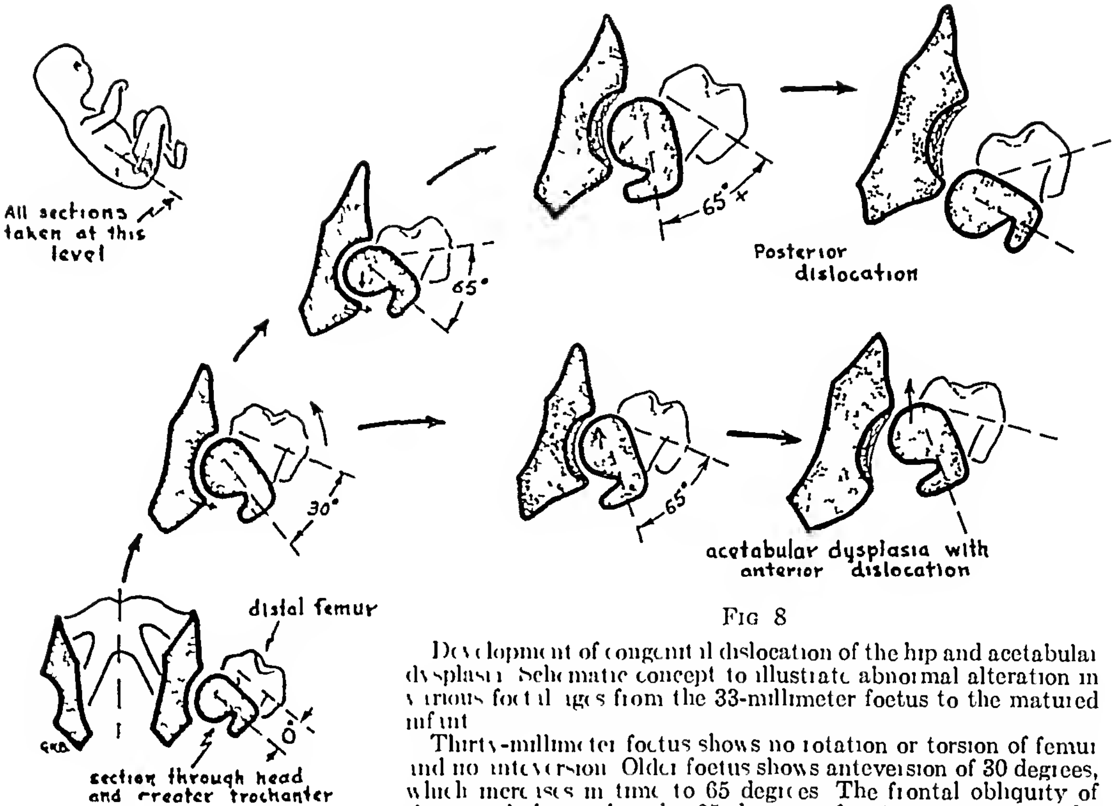

FIG 8

Development of congenital dislocation of the hip and acetabular dysplasia Schematic concept to illustrate abnormal alteration in various foetal ages from the 33-millimeter foetus to the matured infant

Thirty-millimeter foetus shows no rotation or torsion of femur and no anteversion Older foetus shows anteversion of 30 degrees, which increases in time to 65 degrees The frontal obliquity of the acetabulum, plus the 65 degrees of anteversion, turns the head anteriorly away from the socket The stimulus of contact and pressure, to produce normal deepening of the socket and the reciprocal shapes of the socket and the head of the femur, is lacking The head and neck, pointing forward, may rest against the posterior cartilaginous border of the socket and produce hypoplasia The head may then become spontaneously displaced posteriorly

If, however, the delay in the proper timing of the rotation of the head into the socket is minimal or less prolonged as growth continues, anteversion with a malshaped head and a flat socket may develop without the demonstration of a true dislocation, but rather with changes from mild to severe acetabular dysplasia These are adaptive changes to a loss of the normal chronological fit of the head and socket, during the process of adaptation to parallelism of the limbs

1 An increased distance between the upper femoral epiphysis and the acetabular floor,—that is, lateral displacement,

2 Hypoplasia of the bony nucleus for the epiphysis of the head,

3 Increased angulation of the acetabular roof

These changes are not evidence of a primary flat socket or of primary hip dysplasia All can be produced by adaptive changes The anteversion of the head and neck of the femur can be demonstrated by correction of the relationship through internal rotation and abduction only How can one ignore the reciprocal changes in the head and neck in these young infants, or call them secondary changes, when they are as marked a part of the deformity as is the acetabular change? Convention and habit may be the chief reason The author believes that both deformities are reciprocal faults, secondary to a developmental error, possibly both hereditary and environmental in character They are not hereditary in the sense of a gene which fails to develop a part of the acetabulum, but rather a hereditary quality of interference of the timely development of the intrinsic mosaic pattern, producing environmental extrinsic faulty development which leads to the abnormality This is entirely consistent with the known facts of embryological joint development In what other joint formation has there been a failure of development from a primary developmental fault of part of a structure? One cannot compare the failure of approximation of separate components, such as is seen in rachischisis of the spine or cleft palate, with a structure originating as a single mesenchymal mass, differentiating or-

nally as a continuous structure which separates into its conjugate parts after a growth of the foetus to 30 millimeters.

Anteversion

Some observers, including Fairbank, deny the frequency of anteversion in hip dysplasia and dislocations, possibly because of a faulty concept of where anteversion occurs. Anteversion occurs primarily in the diaphysis below the upper epiphyseal line. The head and neck may be in normal relation with the trochanters and yet anteverted in relation to the shaft, or, probably more accurately, torsion of the shaft is increased. Anteversion can occur with retroversion of the head. In fact, retroversion of the head may be a compensatory mechanism for anteversion. Most clinicians feel, however, that anteversion is a common accompaniment of hip dysplasias.

Murk Jansen stated: "In congenital dislocation of the hip, anteversion of the femoral neck . . . is a constant phenomenon." He attributed this to a primary flattening or widening of the socket. Tubby, Hibbs, Kirda, and others have emphasized that anteversion of the neck is a frequent complication of congenital dislocation, usually a secondary phenomenon. Watkins stated that Lange had contended the head of the femur "originally left the acetabulum by the anterior route". He stated that the forward twist of the head and neck on the shaft was apparent in all cases of congenital dislocation in which the patient had walked.

The author has previously stressed that anteversion is not a secondary adaptive change, but is rather an integral reciprocal deformity, resulting and developing concurrently with the changes in the socket, the one dependent upon the other for the extrinsic or environmental factors necessary for the dynamic development of the hip joint. The roentgenographic evidence of an apparent coxa valga is proved faulty when roentgenograms are taken with the lower extremities in internal rotation. The angle of inclination will be found to approximate the normal, demonstrating that coxa valga itself rarely occurs, but anteversion rotates the head and neck outward, producing this false or apparent coxa valga.

Similarly, we have mentioned that Putti's triad is evidence primarily of anteversion and not of true displacement. Internal rotation associated with abduction will show a normal angle of inclination, and the epiphysis is properly replaced in its relation to the acetabulum.

CONCLUSIONS

From the facts presented, it would seem logical to conclude that the etiology of congenital dislocation of the hip is a developmental fault of the hip system produced by extrinsic factors—growth circumstances—with a combination of hereditary and environmental faults which alter the normal growth potential of the intrinsic mosaic pattern. Congenital dislocation and congenital dysplasia are developmental deformities produced by secondary adaptive changes. Inherited characteristics and environmental factors may alter the intrinsic mosaic pattern by a faulty timing in development. Patten states that "local overgrowth may be responsible for certain anomalies, just as local arrests may be responsible for others . . ."

Our concept of congenital dysplasia of the hip and congenital dislocation is that through a developmental fault, the acetabulum has failed to deepen and the head and neck of the femur have become anteverted. The anteversion tends to turn the head forward, displacing the cartilaginous sphere laterally, so that the glenoidal labrum and acetabulum cover less of the head than usual. The poor adaptation of the head and acetabulum continues dynamically to require altered growth changes, altering the intrinsic mosaic pattern. These growth changes are manifested in subluxation or acetabular dysplasia, pushing upward of the glenoidal labrum, widening of the socket, and enlargement of the

head (Fig. 8). If the head escapes completely past the edge of the glenoidal labrum, a true dislocation results. The glenoidal labrum, unobstructed, returns by its elasticity to its proper position, lying between the head and the acetabulum. The head of the dislocated hip no longer has the stimulus for overgrowth seen in the subluxation, so that it remains small and round, although becoming flattened on the side if in contact with the ilium.

This mechanism is in complete accord with the pathological findings in early postnatal hip dysplasias, demonstrated by arthrograms and by operative findings. It is to be remembered that anteversion occurs below the trochanters and actually is associated with torsion of the femoral shaft.

It would seem a logical hypothesis that the rotation of the limb buds may be an important factor in the abnormal development. Presumably there must be an adaptive alteration in the change of position, from the origin of the hip joint in the first few weeks of embryonic life to the 90 degrees of rotation and adduction of the hip in the second four weeks of life. Interference with the orderly timing of this rotation—the embryo being held in a position overlong for even a short time—could produce a failure, mild or severe, in the intrinsic mosaic design. The altered environment could produce the adaptive features which are seen in all the structures of the hip joint, and not a primary change in the acetabulum alone.

These studies lead to the following hypothesis: Congenital dislocation and congenital dysplasia of the hip may be regarded as the result of faulty development, due to environmental factors extrinsic to the hip joint. An inherited fault in the timing of development may produce these extrinsic changes. The loss of the normal dynamic reciprocal relationship of the component parts of the hip joint during the stage of rotational adjustment of the limb buds may produce the secondary adaptive changes which lead to acetabular dysplasia or congenital dislocation. Heredity can play an important part in altering the growth and time factors. The known embryological development of the hip joint is certainly opposed to the theory of a primary inherited failure of development of a portion of the acetabulum.

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CONGENITAL DYSPLASIA OF THE HIP JOINT

Relationship between Congenital Subluxation and Congenital Dislocation *

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Since congenital subluxation of the hip as an entity has not been fully considered before this Academy, or included as such in the chapters on congenital dislocation of the hip in American textbooks, the author believes that the relationship between subluxation and dislocation deserves special attention. Leading European schools recognize this relationship. We will gain a more complete concept of the problems of congenital dysplasia of the hip joint with dislocation if we, too, accept and teach the pathogenesis of subluxation.

If, during embryonic or foetal life, a flat and shallow socket forms or a primary dysplasia of the acetabulum occurs because of genetic and biomechanical influences, either alone or in combination, five possibilities exist for subsequent growth of the hip joint. First, there may be complete displacement between the femoral head and the maldeveloped acetabulum with clinical, roentgenographic, and pathological findings of classical posterior dislocation or superior dislocation of the hip. Second, the displacement between the femoral head and the flat socket may be incomplete, but always with some contact of the articular surfaces of the head, socket, and limbus, and without capsular interposition. This condition, known as congenital subluxation, is also a distinct clinical, roentgenographic, and pathological entity. It is now an established fact that congenital subluxation of the hip, which was thought to be only a precursor of the classical dislocation, may remain throughout life as a permanent and eventually a disabling deformity. Third, there may be no displacement between the femoral head and the shallow dysplastic acetabulum. This condition also may be a definite clinical entity and remain as such throughout life (Fig. 1).

These three hip-joint entities, therefore, are identical in their etiology, but differ in their clinical and roentgenographic manifestations. There is also a fourth and rare entity, associated with extreme dysplasia, shortening of the shaft of the femur, and irreparable malformations of all structures of the hip joint. All four entities are definite clinical expressions of congenital dysplasia of the hip joint and have a common etiology.

Fifth, the dysplastic hip, with no treatment, may return to normal during either intra-uterine life or early infancy, as a result of the rare phenomenon of spontaneous recovery (Figs. 2-A and 2-B).

If it is true that congenital dysplasia of the hip is always bilateral during embryonic or early foetal life, then unilateral postnatal dysplasia of the hip, with or without displacement of the femoral head, must denote spontaneous healing of the opposite, apparently normal hip joint. If all dysplastic hips possessed the full capacity for spontaneous recovery, congenital subluxation and dislocation would never become serious problems. No one knows the potential capacity of the structures of the dysplastic hip to return, partially or completely, to normal. The growth capabilities of the tissues may be temporarily or permanently inhibited, with varying degrees of malformation. Whether the inherent capability for recovery is feeble or abundant, it is axiomatic that age is the most important factor in influencing the results of treatment of congenital dysplasia of the hip. A favorable mechanical and functional position, obtained by treatment during the period of infancy before weight-bearing, not only enhances the potential growth power of

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 27, 1948.

the maldeveloped hip joint, but also prevents secondary pathological changes During this age period, dysplasia of the hip with subluxation is common, with dislocation, rare

The purpose of this study is, first, to focus attention on congenital subluxation, which is frequently unrecognized as a distinct entity and often coexists with classical dislocation of the opposite hip, and, second, to establish the common etiology of the two conditions

To prevent confusion, one must understand that all congenital dislocations and subluxations are not the result of primary dysplasia or maldevelopment of the acetabulum Spina bifida with paralysis of an extremity, intra-uterine flexion-adduction of the hip in breech posture with the foot placed over the shoulder, intra-uterine chondro-osteodystrophy, and intra-uterine muscular dystrophies with degenerative fibrosis and contractures of muscles, as seen in myodystrophia foetalis or arthrogryposis multiplex congenita may cause displacement of the femoral head from the acetabulum

Congenital subluxation should not be confused with residual subluxation In congenital subluxation, the hip has at no time been dislocated Residual subluxation is a partial redisplacement of the femoral head, subsequent to closed or open reduction of a dislocation or to failure to obtain complete reduction Residual subluxation of some degree occurs in the great majority of dislocated hips after reduction

One is not justified in attempting to explain all congenital displacements of the hip on the basis of a single mechanism There are several causes of congenital dislocation and subluxation before birth, just as there are several causes of hip-joint displacement after birth In this paper, the discussion is limited to the displacement of the hip joint which is

FIG 1

Bilateral flat dysplastic socket with practically no upward displacement Each femoral head is broadened in its transverse diameter and is irregular (coxa magna) The patient is now in early adult life and has no disability except fatigue in the hip and low back after strenuous exercise Traumatic osteoarthritis will gradually develop because of the hip-joint incongruity Osteochondritis dissecans has been observed as one of the dysplastic sequelae in this type of hip malformation, and probably is developing in this case

FIG 2-A

FIG 2-B

FIG 2-A Roentgenogram taken in October 1945, when the child was one year of age, revealed a flat, shallow dysplastic acetabulum with pronounced subluxation of the femoral head from the socket There was delayed and hypoplastic development of the ossification center of the femoral head She walked with a slight limp Clinical examination of the left hip joint demonstrated shortening of the extremity, slight telescoping, and limitation of abduction Abduction treatment was refused

FIG 2-B Roentgenogram, taken in April 1948, revealed normal structures of the left hip joint, except for slight hypoplasia and irregularity of the nucleus of the head Clinically the hip joint and extremity were normal There had been no treatment since the examination in 1945

This is the only case of spontaneous healing of congenital dysplasia of the hip joint with displacement ever seen by the author Probably this phenomenon is common during prenatal life and early infancy (Courtesy of Dr H J Fortin, Fargo, North Dakota)

Fig 3

Classical congenital dislocation of the right hip and congenital subluxation with coxa plana of the left hip Neither hip joint had been treated The irregular and delayed calcification of the femoral head may be an expression of epiphyseal dysplasia

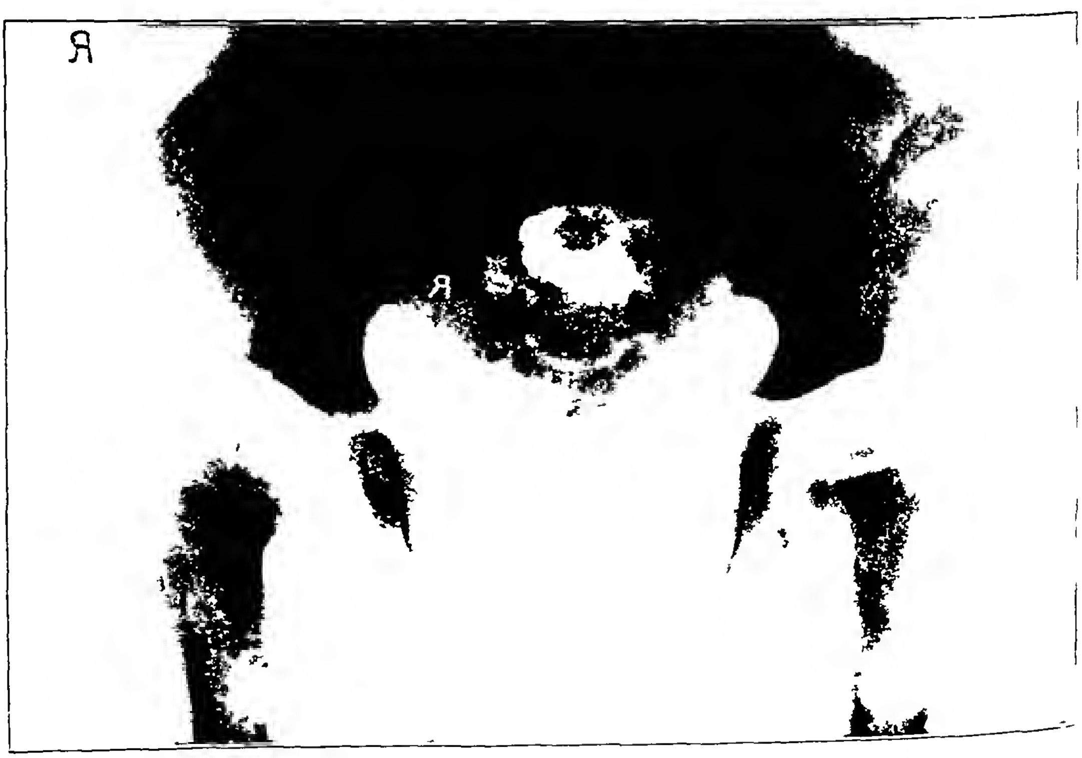

Fig 4

Congenital subluxation of right hip joint with evidence of coxa plana or epiphyseal dysplasia This child had never been treated The patient's aunt had congenital dislocation of the hip

FIG 5

This patient, twenty-four years of age, had had no trouble with the right hip until two weeks before examination, when she strained it while bowling Observe the primary flat socket with secondary subluxation and early traumatic osteo-arthritis of the right hip, and classical dislocation of the left hip joint The dislocated left hip is painless, the subluxated right hip is painful The patient's hip joints had never been treated This patient's mother has congenital subluxation of one hip with extensive osteo-arthritis

The characteristic forms of the subluxated and the dislocated femoral heads may be seen In subluxation the head is hypertrophied It is widened in its transverse axis and flattened in its vertical axis It may represent the adult stage of coxa magna or late deformity of epiphyseal dysplasia In dislocation the femoral head is small and atrophied

caused by an osseous and cartilaginous defect, or by aplasia of the superior and posterior supports or buttress for the head of the femur The author believes that this defect has a genetic or biomechanical etiology, or a combination of the two, and that it is a constant primary malformation in congenital dysplasia of the hip Primary dysplastic features are not limited to the acetabulum, but may involve all mesodermal structures of the hip joint The many secondary pathological features or dysplastic sequelae which develop gradually during a period of months or years may be explained on the basis of laws of bone growth, aseptic necrosis of bone and cartilage, and traumatic osteo-arthritis

For many years, physicians have been interested in explaining the form and structure of the normal and the abnormal hip joint Keith wrote that, in 1838, Mr F O Ward, who demonstrated anatomy at King's College, London, explained for the first time the architecture of the femoral head and neck He compared the two groups of bone trabeculae in the femoral neck with a triangular bracket supporting a street lamp, the ascending supports being subjected to pressure and the horizontal supports to tension The architecture of the femoral neck is a perfect mathematical design for the transference of weight Keith states "Hunter discovered that the elaborate architecture of the neck was being continually remodelled from infancy to adult life, without such remodelling, the femoral shaft could not grow" A study of the head and neck of the femur gave Wolff the key to his law of bone transformation, which he expressed in 1885

The shape and form of normal and abnormal hip joints have been investigated by

FIG. 6-A

In addition to the characteristic features of primary hip dysplasia with acclivity of the acetabular roof, secondary changes of subluxation and traumatic osteo-arthritis with loss of joint space, sclerosis, cystic rarefaction, and double acetabular floor are present. The patient's symptoms began at the age of forty. She was totally disabled for work and was not relieved by conservative measures. The hip was treated by arthrodesis. Her sister is disabled with bilateral hip dysplasia and dislocations.

many physicians over the years. Keith has stated that the osteoblasts, influenced by static and dynamic forces, are the engineers of the hip joint and do their work according to exact mathematical laws. A study of the pathogenesis of congenital subluxation and congenital dislocation of the hip joint from the foetus through adult life explains many of the interesting phenomena of bone and cartilage growth.

Evidence to support the common etiological relationship between subluxation and dislocation is available from many sources.

1. *The Literature*

For many years, physicians believed that subluxation was only the precursor of dislocation, and that a subluxation never remained stationary throughout life, but always progressed to complete displacement. According to Wiberg, the term "subluxation" was introduced by Paletta in 1775, on the basis of autopsy findings. Parise recognized the distinction between complete and incomplete dislocation in 1842. Sayre, in 1876, wrote: "The real difficulty in this condition, which has been termed congenital dislocation, but which I prefer to call congenital misplacement, consists in the *malformation* of the acetabulum, namely, a non-fusion of the three bones which enter into its construction. The cavity of the acetabulum being incomplete, the head of the femur rides through the opening left, and is found upon the dorsum of the ilium." According to Wiberg, the first publication of a case of subluxation on the basis of clinical and roentgenographic findings was by Zenker in 1897. Wiberg also stated that Hoffa and Lorenz believed that subluxation was a transitional stage, and that dislocation would always result as the child started to bear weight. As late as 1937, Albee stated: "The dislocation may be *complete* or *incomplete*

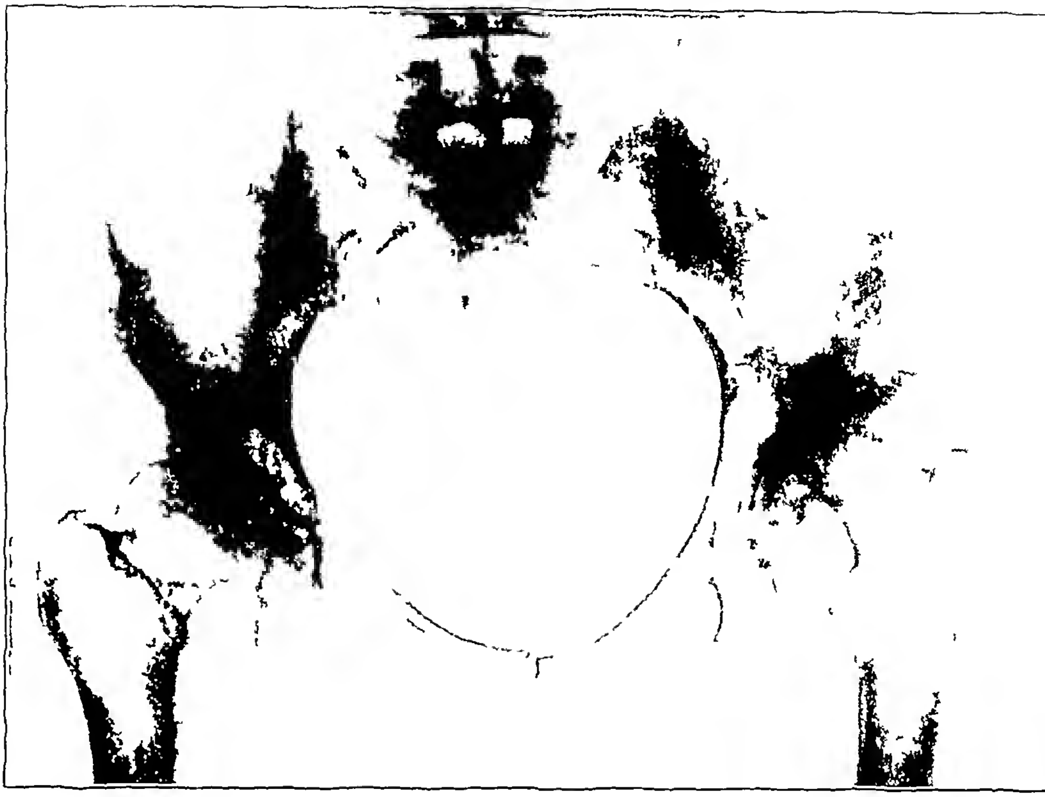

Fig 6-B

Roentgenographic study of a housewife, forty-six years of age Pain started in the left hip at the age of twenty-five, in the right hip, at the age of thirty-one She continues with her work and does not use a cane or crutch Pain and disability of the left hip are increasing gradually The patient's brother has congenital dislocation of both hips

The primary dysplastic features involve both acetabula, which are flat and inadequate The secondary pathological changes of subluxation, malformation or coxa magna of the femoral heads, and traumatic osteo-arthritis, which is extensive on the left side, may be noted Shenton's line is disturbed on each side (See Fig 10)

The latter, in which the head is not entirely out of the acetabulum, is only a step in the process"

Albert Freiberg, in 1904, published the first and one of the most valuable studies in this country of congenital subluxation of the hip in infancy The first demonstration that subluxation could remain during life as a definite and disabling entity was made by Gourdon in 1906 Gradually more and more surgeons reported their clinical experiences and belief that subluxation was not only the forerunner of dislocation, but that it frequently remained as a stationary deformity and a disease entity The monumental work of Putti firmly established subluxation as a distinct clinical, pathological, and roentgenographic entity He pointed out that recognition of subluxation and its treatment in the infant, before weight-bearing begins, is "the only secret that can improve the results of the treatment of congenital dislocation of the hip" (Figs 8-A and 8-B)

Howorth and Smith, in 1931, reported a detailed study of seventy-two congenital dislocations treated by open operation They stated "Seven per cent of the hips were only subluxated and ninety-three per cent were completely dislocated" Gill, in his many excellent contributions on congenital dislocation of the hip, has described the morbid anatomy of congenital subluxation and the surgical treatment by acetabular reconstruction

In 1932, Colonna published his method of arthroplasty for congenital dislocation and subluxation Since then he has made careful follow-up studies, a report of the end results was published in 1947 Colonna's two-stage procedure for obtaining functional hips in children under eight years is an important contribution

Joseph Freiberg, in 1934, wrote a very instructive paper on the early recognition and treatment of dislocation, in which he stated: "Up to 6 months of age, and sometimes until the walking period, the dislocated femoral head lies lateral to the acetabulum and level with the superior margin of the acetabulum." McCarroll and Crego, in 1939, stated: "Three distinct types of congenital dislocation can be clearly recognized and differentiated. The first of these is the classic posterior dislocation. . . . The second type consists merely of an upward subluxation. . . . The third type of dislocation is that which exists in a true anterior position. . . ." (This is actually a superior dislocation with anteversion of the neck.) In 1939, Wiberg wrote an excellent review of the history of subluxation. Ryerson, in 1941, described his shelf operation for "congenital subluxation of the hip" and other conditions with instability of the hip joint. Ponseti, in 1944, classified five types of congenital dislocation of the hip, one of which he described as follows: "The subluxation, where, in spite of a shallow acetabulum and upward displacement of the head of the femur, a complete dislocation never occurs."

2. *Clinical Histories*

It has been observed frequently that congenital dislocation of the hip, coxa plana, coxa valga, subluxation, coxa magna, and malum coxae senilis may affect various members of the same family. The parent of a child with dislocation may have arthritis deformans of one or both hip joints. The author has seen several children with Legg-Perthes disease or coxa plana, whose aunt, uncle, or other relative had dislocation of the hip. He has also seen several children with classical dislocation of one hip and coxa plana or epiphyseal dysplasia involving the "healthy" hip. Jansen, in 1923, referred to coxa plana as the "satellite" of congenital dislocation of the hip (Figs. 3 and 4). It is not uncommon to see an adult with a painless untreated congenital dislocation of one hip and a painful subluxation of the opposite hip which, for years, had been considered normal, until an acute strain or traumatic osteo-arthritis developed (Fig. 5). A frequent experience is to observe a patient with congenital subluxation, who has a relative with congenital dislocation (Figs. 6-A and 6-B). It is little wonder that many writers have considered a hereditary etiology for these various diseases of the hip joint. Not until 1937, however, was a truly scientific study made by Faber to determine their hereditary nature.

3. *Clinical and Roentgenographic Examinations*

It is unusual to observe dysplasia of the hip with some degree of displacement or subluxation in a child, unless the child is under treatment for dislocation of the opposite hip. There are no subjective symptoms or objective clinical findings during infancy in hip-joint dysplasia without displacement of the femoral head. However, dysplasia with subluxation, which is often the precursor of dislocation, can be recognized in the infant (Figs. 7-A and 7-B) or later, after the child begins weight-bearing, as a dislocation or as a pronounced subluxation. The displacement must be considered a subluxation as long as some contact remains between the femoral head and the articular surface of the dysplastic and inadequate acetabulum. Waldenström stated: "By subluxatio coxae congenita we understand a condition which may be best characterised by the words 'on the way to luxation'." Dislocation occurs when the displacement increases and there is no contact of articular surfaces of femoral head and sloping socket.

The infant with subluxation presents well-known clinical and roentgenographic changes by which the condition may be diagnosed. In every instance these signs may be demonstrated before the fourth month of life or before the appearance of the epiphyseal nucleus of the femoral head. These infants' hips will either progress to dislocation or remain in severe subluxation without treatment, unless spontaneous recovery occurs.

At a later age during childhood, because the child complains of hip fatigue, pain, and limp after exertion, dysplasia of the hip with coxa plana or aseptic necrosis of the femoral

FIG 7-A FIG 7-B

Fig 7-A Six-week-old male infant with congenital subluxation of the right hip joint Clinical examination demonstrated marked limitation of abduction of the hip because of adductor contractures, slight shortening, and asymmetry of the thigh folds and creases There is delayed ossification of the ischiopubic juncture on the right

Fig 7-B Roentgenogram four and one-half months later, no treatment having been given The clinical findings have not changed The roentgenographic features of congenital dysplasia of the right hip with subluxation are obvious Observe (1) the flat and inadequate socket with sloping acetabular roof, (2) delayed development of the center of ossification of the femoral head, (3) delayed closure of the right ischiopubic juncture, (4) slight upward and lateral displacement of the femoral head from the socket, (5) position of adduction of the right lower extremity because of adductor contractures, and (6) the disturbed Shenton line (Draw the Y line [Hilgenreiner] and the vertical line [Perkins] to form the quadrants and observe the relationship of the nucleus of each femoral head to these lines and the quadrants)

FIG 8-A FIG 8-B

Fig 8-A Abduction pillow splint which Professor Frejka, of Czechoslovakia, demonstrated before the Annual Meeting of The American Academy of Orthopaedic Surgeons in 1947 Complete abduction and complete reduction are gradually accomplished by the continuous pressure of a pillow, filled with down or kapok, which is placed between the two layers of the splint Medium-weight cotton twill or mattress ticking is the best material for making the splint Soiling is prevented by placing waterproof material between splint and diapers The splint is efficient and inexpensive, and provides active instead of passive immobilization The active muscular function which is permitted in this splint prevents atrophy, contractures, and adhesions Certainly the physiological stimuli of normal pressure and motion must enhance the potential capacity for reforming the flat and dysplastic socket, in accordance with the laws of bone growth

Fig 8-B Back view of the Frejka splint Standing and walking are encouraged at the proper time

Fig 9

Note the characteristic features of primary dysplasia of the acetabulum (Calot's half-citron socket) There is physiological adaptive sclerosis of the acetabular roof or very early osteo-arthritis Note the disturbance of Shenton's line The patient, a young woman, complained of hip fatigue and a mild limp when tired Symptoms were completely relieved by rest and change of occupation The opposite hip is normal The patient's sister is disabled by a hip dislocation

head may be found (Figs 3 and 4) During late adolescence and early adult life a dysplastic hip is frequently observed, because of attacks of hip pain with limp and atrophy of the thigh There may be no limitation of hip motion or shortening of the extremity Only by roentgenographic studies is the dysplastic flat, citron-shaped socket recognized (Figs 9 and 10) The earliest finding of osteo-arthritis—increased sclerosis of the weight-bearing portion of the acetabulum—may be found at this time, in addition to the primary features of hip-joint dysplasia with slight or pronounced subluxation

In middle life, advanced osteo-arthritis may develop secondary to subluxation, and cause serious disability (Figs 6-A and 6-B)

4 *Roentgenographic Studies of the "Normal" Hip in Patients with Unilateral Classical Dislocation*

The most convincing evidence of relationship between subluxation and dislocation is found in patients who have positive roentgenographic findings of both entities, involving the two hip joints (Figs 11 and 12) Wiberg wrote that Hoffa had made this observation in children, but had stated that the subluxation would always develop into a dislocation as the child grew Wiberg also stated that, as early as 1900, Bade found hypoplasia of the roof on the "healthy" side in 25 per cent of unilateral dislocations, "and he thought that the more careful technic of the future would leave hardly any unilateral cases" Severin reported, in 1941 "Re-examination of the original roentgen pictures showed that 57 of the 'healthy' hips in 190 unilateral cases suffered from definite dysplasia or subluxation when the other was treated" Ponseti, in 1944, studied the so-called normal hip in eighty-five cases of unilateral dislocation He observed that the "normal" hip was well

FIG 10

Roentgenographic study of a twenty-year-old physical-education student, who had no complaints except mild pain and a feeling of fatigue, involving the region of the left hip, following strenuous exercise Observe the bilateral flat dysplastic socket with mild subluxation of the right femoral head and pronounced subluxation of the left femoral head The absence of coxa magna deformity of the femoral heads may be evidence that epiphyseal dysplasia did not exist during the growth period The disturbance of Shenton's line is slight on the right side, but marked on the left Gradually over the years traumatic osteo-arthritis will develop in both hip joints because of their dysplastic incongruity and malformation (Courtesy of Dr E F Chambers, Seattle, Washington)

formed in forty-seven cases, and in the remainder, it showed some defect as proof of its congenital dysplasia No one knows what percentage of these well-formed hips had been changed from a state of dysplasia to normal by spontaneous recovery, without benefit of special treatment

Fairbank observed in 1929 "Many surgeons, however, including myself, have been impressed with the frequency of pain and other signs of arthritis in a congenitally unstable or subluxated joint previously regarded as normal, while the opposite hip, completely dislocated, gives no trouble" Waldenström, in 1932, stated "It is of fairly common occurrence that a luxatio congenita on the one side occurs together with a subluxation on the other" Jansen, in 1929, discussed coxa plana involving the "normal" hip in children with unilateral dislocation of the opposite hip The author has had the same experience and believes that aseptic necrosis of the femoral head or epiphyseal dysplasia may be one of the many consequences or expressions of hip-joint dysplasia (Figs 3 and 4)

While reviewing the literature on hip-joint dislocation, one observes a large number of illustrations which demonstrate a markedly flat or dysplastic hip with varying degrees of subluxation involving the "normal" hip The high incidence of coexistence of dysplasia with dislocation of one side and dysplasia with subluxation of the opposite hip is convincing evidence of a relationship or common etiology of the two entities (Figs 11 and 12)

5 *Observations of Residual Subluxation*

Residual subluxation is a partial displacement of the femoral head from the socket, subsequent to closed or open reduction of a dislocation This is a common complication

FIG 11

The most convincing evidence of relationship between congenital subluxation and congenital dislocation is found in patients who have positive roentgenographic findings of both entities, involving the two hip joints

Roentgenogram shows bilateral dysplasia of the hip joints in a child, six years of age, with dislocation of the left hip and subluxation of the right hip The hips had never been treated The right or subluxated hip caused no complaints and had been considered "normal" (See Fig 12)

following reduction, but one to be expected if later there is insufficient development of the acetabular roof If the residual subluxation does not continue toward displacement with weight-bearing, but remains a fixed and permanent condition, it may then be compared with the congenital subluxation which also is fixed and permanent The two conditions are now the same in many anatomical and mechanical features One would not expect them to be identical, because of the more marked secondary changes which had developed in the ligamentum teres, Haversian gland, capsule, limbus, femoral shaft and neck (antetorsion), and femoral head on the dislocated side before reduction, but they continue to have a similar clinical course throughout life There is usually good stability and function during childhood, adolescence, and early adult life, but during middle adult life serious disability begins Osteo-arthritis is then superimposed, because of the trauma of instability and the incongruity of the functioning articulation over the years At this stage the clinical, roentgenographic, and pathological features of arthritis deformans are the same in the two entities

6 *Arthrographic Studies*

Arthrographic studies should be reserved for scientific research Clinical and roentgenographic findings are sufficiently accurate for all practical purposes Arthrographic studies, however, have added a great deal to our knowledge of the normal and the pathological hip joint Severin, Faber, Leveuf, Wiberg, Stewart, and others have made important contributions

7 *Genetic, Embryological, and Anthropological Investigations*

The writer is familiar with only one genetic investigation which provides accurate and scientific evidence of a relationship between subluxation and dislocation of the hip

Faber, in 1937, reported his roentgenographic consanguinity studies of the families of ten children with classical dislocations, who were considered ostensibly sound in their heredity. All genetic studies made prior to Faber's monumental contribution had been founded on the concept that the dislocation was the inherited trait. They had been based only upon the data of actual clinical dislocations of patients whose parents or relatives also had dislocations. Faber based his concept on the fact that the hereditary factor, upon which dislocation depends, is not the hip dislocation itself, but instead is a primarily existent defect in the joint, designated by Hilgenreiner as congenital dysplasia of the hip joint or a flat socket. Subluxation, as well as dislocation, is a consequence of the primary genetic dysplasia or incompetent acetabulum.

Previous authors had agreed that, in 20 per cent. of all cases of dislocation of the hip, they observed a genetic occurrence in families. The anatomy of the hip joints of all persons having blood relationship could not possibly have been evaluated properly unless clinical and roentgenographic studies of the hip joints of each individual had been available. Faber demonstrated that, in the families which he investigated roentgenographically, primary dysplasia of the hip with subluxation was three times as frequent as was classical dislocation. He also found dysplasia with osteochondrosis deformans in children and malum coxae senilis or arthritis deformans in middle life, findings which coincide with observations in clinical practice. The writer has observed that subluxation, like dislocation, is more common in the female.

Embryological studies have added no positive evidence to our understanding of congenital dysplasia of the hip joint, although work in this field, such as that of Strayer, should be encouraged.

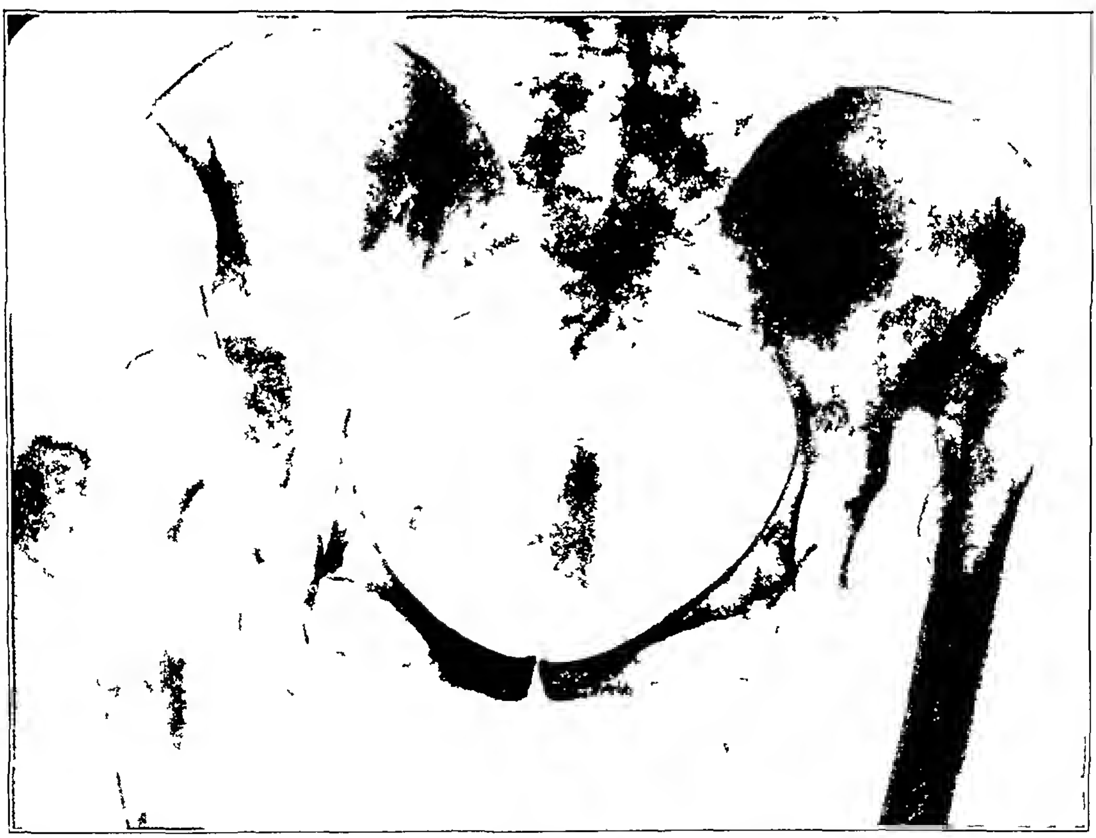

FIG. 12

Bilateral dysplasia of the hip joint in an adult, thirty-eight years of age, with dislocation of the left hip and subluxation of the right hip. The hip joints had never been treated. The subluxated hip had been considered "normal" until the age of thirty-six, when pain first appeared because of traumatic osteo-arthritis. The characteristic hypertrophy or coxa magna of the subluxated femoral head and atrophy of the dislocated head are visible.

Bohm, in 1932, stated "We know clinically that the infantile deformities have a tendency to familial and hereditary appearance and that anatomically their morphological substratum is identical with the normal conditions of certain animals, such as the anthropoid The acetabulum of the human foetus shows the same characteristics as that of the gorilla the posterior roof is entirely lacking The human foetus has likewise an acetabulum of oval shape Thus I consider the infantile deformities as congenital in a wider sense"

8 *Pathogenesis of Arthritis Deformans*

Preiser in 1907, first mentioned that congenital subluxation was the most important etiological factor in the development of osteo-arthritis of the hip joint Putti, in 1933, stated that 40 per cent of all cases of arthritis deformans of the hip or malum coxae senilis are the result of congenital subluxation Wiberg, who observed the development of osteo-arthritis in nineteen cases of congenital subluxation, believed that in about every fourth hip with arthritis deformans the condition is originally due to subluxation (Figs 6-A and 6-B)

9 *Surgical Observations*

At the time of open reduction for acetabular reconstruction or arthroplasty in children, one frequently finds some contact between the articular cartilage of the femoral head and the articular cartilage of the acetabulum The femoral head lies against the deficient portion of the roof and limbus of the socket There is no isthmus of the capsule It is rare to observe a constriction of the capsule between the acetabulum and the femoral head before the age of three years The head is on its way to dislocation, but the actual pathological finding is subluxation, secondary to dysplasia of the hip and slight stretching of the capsule This is a common observation at open reduction before the age of four years, it would be a very common finding if one opened the hip joints of infants before the age of weight-bearing

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DISCUSSION

DR PAUL C COLONNA, PHILADELPHIA, PENNSYLVANIA A clear differentiation of the two manifestations of hip dysplasia, to which Dr Hart has again called our attention, has long been present in the writings of the European surgeons We have at this meeting one of the outstanding authorities on this interesting subject, Professor Leveuf I hope he will comment on this paper Dr Hart had to delete a part of his paper because of lack of time, but I should advise a careful study of it when it is published

He and others have defined true congenital dislocation as a condition in which the head is not in contact with the acetabular cartilage, while in incomplete dislocation, or subluxation of the hip, some contact with the cartilage is retained, without capsular interposition Gourdon stated over forty years ago that he believed subluxation to be a relatively stable condition that never developed into luxation Some of us may question this in the light of our personal experience, but certainly we would agree with Dr Hart that subluxation should never be regarded as *only* a transitional stage of dislocation We believe that in the great majority of subluxated hips, the condition remains essentially stationary The widening of the joint space, the limitation of abduction, and the slight upward riding of the greater trochanter can be recognized quite early, and Putti stressed the use of abduction as a simple curative measure in young infants

The shadow representing the nucleus of the head is not visible at birth, and its development is delayed in the dislocated hip In my opinion, it is only after the third or fourth month of life that one can begin to recognize definitely the presence of subluxation of the hip from the roentgenograms

Professor Leveuf has shown, by the use of arthrograms, that the cotyloid cartilage or limbus is forced upward, producing a flat saucer-like socket in the cases of subluxation, while there is a cartilaginous cuff

along the superior rim in the cases of luxation or dislocation This probably will add greatly to our information regarding not only dysplasia of the hip, but also other non-infectious conditions

In a recent Scandinavian journal, Gade cited 123 osteo-arthritic hips which had been operated upon, 47 per cent of which presented some degree of congenital dysplasia This means that the recognition of these hip dysplasias and their immediate treatment is very important

We would like again to congratulate Dr Hart on stressing the matter of early recognition and pointing out various aids in the differentiation of the two entities, both of which are the result of a primary genetic dysplasia of the joint We have, in addition, been impressed with other congenital anomalies that have been found in cases with frank dislocation The frequent lack of fusion of the fifth lumbar or upper sacral segment, noted in the older child, indicates that the congenital maldevelopment is often not limited to the hip-joint structures

We would like to reiterate the danger of our attention becoming focused upon the frankly dislocated hip, while the subluxation or incomplete dislocation of the opposite hip is disregarded We should remember that both hips are sources of potential trouble and need proper care

Dr H Relton McCarroll, St Louis, Missouri No one doubts the existence of the upward subluxation as a developmental defect in these hips Although Dr Hart did not have time to present his entire paper, I believe he is trying to cover too much territory with his theories regarding this anomaly

I would like to limit my discussion primarily to three points First, I believe that upward subluxation of the hip is not so common as Dr Hart indicates There are three primary types of dislocation,—the primary posterior dislocation, the primary anterior dislocation, and the simple upward subluxation In our series of 111 cases seen between 1935 and 1945, we had sixty-eight primary posterior dislocations, twenty-five primary anterior dislocations, and eighteen upward subluxations

The second point has to do with the diagnosis of an upward subluxation at the time of birth Any one who is accustomed to examining these infants or seeing their roentgenograms is fully aware of the tremendous variation that exists in these hips in normal individuals I am not sure that these variations or characteristics are invariably indicative of an upward subluxation We have seen hips of this type in which we have been unable to demonstrate instability, have followed the patients, with repeated x-ray studies, and have found that often these findings disappeared spontaneously In a high percentage of cases, in fact, these hips will be normal at the end of one or two years without any treatment

The third point concerns the assumption of a genetic relationship in this type of involvement One may suspect it, but there has been no scientific evidence or proof of genetic influence on these various developmental defects I think it has to be entirely discarded in the light of our present knowledge

I would like to ask Dr Hart how he can be sure that there are many types of intra-uterine dislocation of the hip

MUDr Jaroslav Slavik, Prague, Czechoslovakia I have three remarks to make First, Dr Hart is right when he says that congenital displacement of the hip is very common Statistics determined at Charles University (in Pilsen and Hradec Králové) during the last two years have disclosed that fully 20 per cent of newborn infants were afflicted with congenital dysplasia of the hip of a greater or lesser degree Because of this extremely high rate, nearly every newborn child in the university towns in our country is submitted to x-ray studies of the hip at the age of three weeks and again at the age of three months We believe that we recognize this disease sooner than the period of middle adult life, and sooner than Dr Hart claims he recognizes it Very often there is first preluxation, which develops into subluxation and finally into luxation in the same hip

Second, Dr Hart says that in congenital displacement of the hip, sometimes under the influence of function, a normal hip joint develops He has based this opinion only on the normal x-ray picture, but microscopically I have found abnormal changes I have a book of seventy-five microscopic specimens of ligamentum teres which were removed in a series of 150 consecutive open reductions for congenital dislocation of the hip, fractures, and Perthes' disease I found, for instance, that between the ages of seven and sixteen, an acute rupture of the ligamentum teres or an acute second stage of obliteration of the blood vessels of the ligamentum teres occurs At this time the epiphyseal cartilage still remains open, and the head of the femur is extremely vulnerable to slight trauma The age from seven to sixteen is the period at which Legg-Perthes disease develops I believe that this disease occurs only in congenital displacement of the hips

Third, in Europe we use the term "preluxation" as indicating the precursor of classical subluxation We find in this condition (1) a poorly developed shelf of the socket, and (2) delayed development of the ossification center of the head of the femur There are, however, more than two clinical manifestations of the same genetic dysplasia

Dr Vernon L Hart (closing) Dr McCarroll is correct that a scientific genetic study has never been made in this country Any such study requires roentgenographic consanguinity tests, such as those made by Faber in 1937

(Continued on page 384)

INJURIES OF THE LATERAL LIGAMENTS OF THE ANKLE

A Clinical and Experimental Study*

BY MORTON H. LEONARD, M.D., COLUMBIA, MISSOURI**

From the State Crippled Children's Service, University Hospitals †, Columbia

Spontaneously reduced subluxations of the ankle often masquerade as sprains [1-7]. They are frequently undertreated by local procaine infiltration and adhesive strapping, with prolonged temporary and occasionally permanent disability for the patient. On the other hand, the author believes that the plaster immobilization which these injuries require is often prolonged unduly. To clarify the relative importance of the lateral ligaments in maintaining ankle stability and for better visualization of the mechanism of inversion injuries to these ligaments, a series of cadaver experiments were performed.

CLINICAL FINDINGS

Fifty-one cases of inversion injury of the ankle were studied. Twenty-three patients were shown roentgenographically to have had spontaneously reduced subluxations. In all instances, both ankles were x-rayed in inversion following general or local anaesthesia, and a difference in the degree of parallelism between the articular surfaces of the talus and of the tibia on the two sides was considered diagnostic of a spontaneously reduced subluxation of the ankle [1,2,5]. When the condition was diagnosed as subluxation, the ankles were immobilized in skin-tight walking plasters for six weeks. These casts were kept skin-tight, as the swelling subsided and the muscles underwent atrophy, by changing them approximately every three weeks. The patients, all college students, were able to attend their classes, and the more aggressive danced and even bowled while so immobilized.

Following removal of the plaster, the foot and ankle were wrapped with elastoplast for about two weeks, principally to minimize the oedema, and roentgenograms were then taken with the ankles in forced inversion. The follow-up roentgenograms showed completely stable ankles in all twenty-three cases.

In twenty-four cases the ankles were stable roentgenographically and were treated by procaine injection and adhesive strapping. Seven of these twenty-four patients had persistent disability, complaining of swelling and a feeling of insecurity, as well as of pain over the anterior talofibular ligament, for as long as they were followed (two to five months).

Four were cases of recurrent injury. The ankles were grossly unstable, as a result of inadequate treatment of acute injury in the past. One man, twenty-five years old, with a ten-year history of repeated inversion of the ankle, already showed clinical as well as roentgenographic evidence of traumatic arthritis, in addition to gross ankle instability.

Some, including Watson-Jones, advise at least ten weeks of immobilization before an acute instability of the ankle is treated. The writer believes that this is too long. With the disappearance of ecchymosis and ligamentous tenderness being used as an index, all but a few of the twenty-three patients treated for acute injury required six weeks of plaster encasement. These few ankles were kept in plaster one or two weeks longer. As noted previously, this period of immobilization, followed by two or three weeks of strapping with elastoplast, gave stable, symptom-free ankles in all twenty-three cases treated.

From the literature, the writer could not determine the relative importance of the

* Presented at the Meeting of the Chicago Orthopaedic Society, March 12, 1948

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† Service of William J. Stewart, M.D.

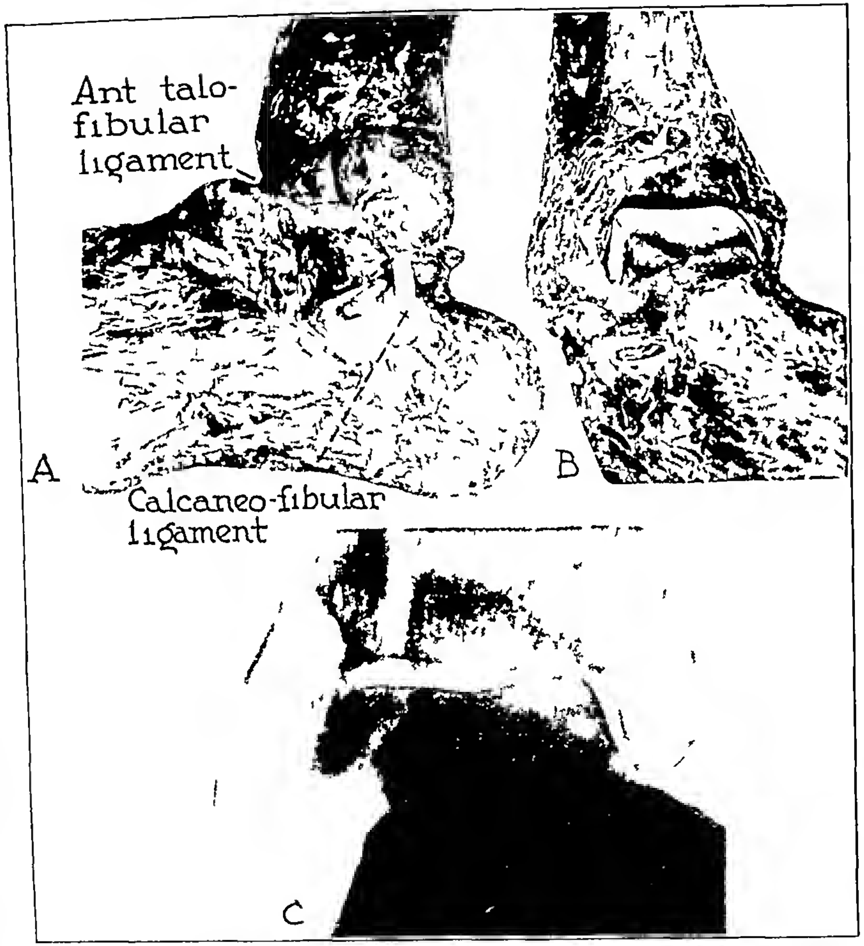

Fig 1

A Course of the lateral ligaments with the foot at an angle of 90 degrees with the leg
B Inversion of foot at 90 degrees
C Ligaments are intact Note the minimal instability (5 degrees) Clinically, this is important if the other ankle is stable [2]

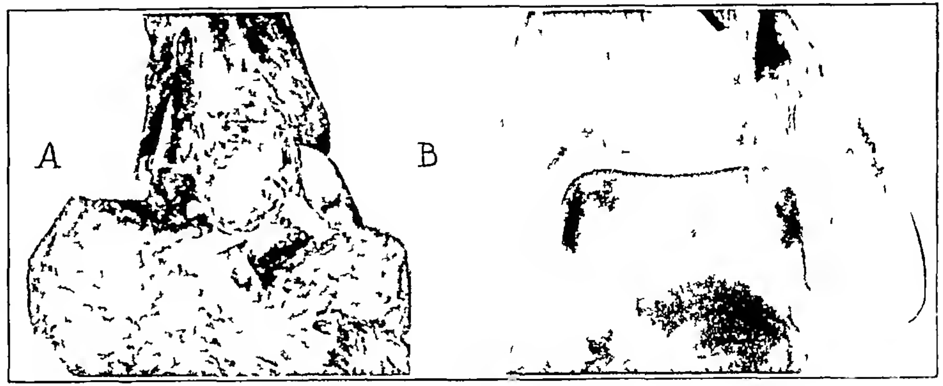

Fig 2

A Course of ligaments with foot in equinus
B Inversion of foot in equinus with ligaments intact

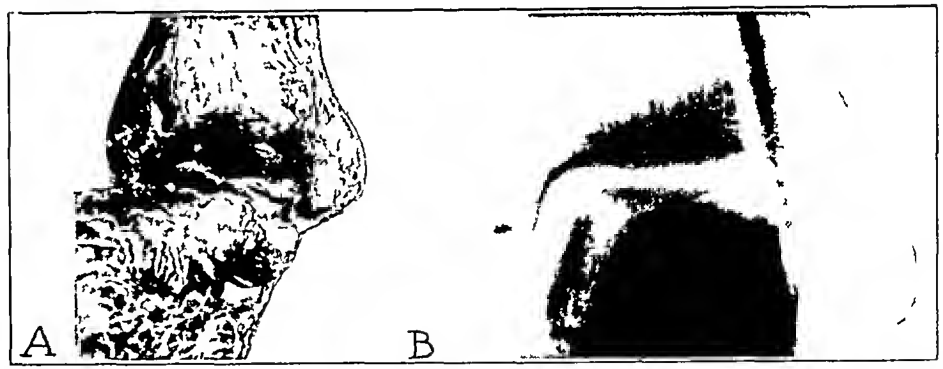

Fig 3

Anterior talofibular ligament has been cut and inversion is at 90 degrees
A In photograph, note the instability in the axis of the tibia (angle *T* is 10 degrees) as well as in the long axis of the talus (angle *A* is 10 degrees) (See Fig 4, *C*)
B This roentgenogram was made on a different cadaver, which showed no instability

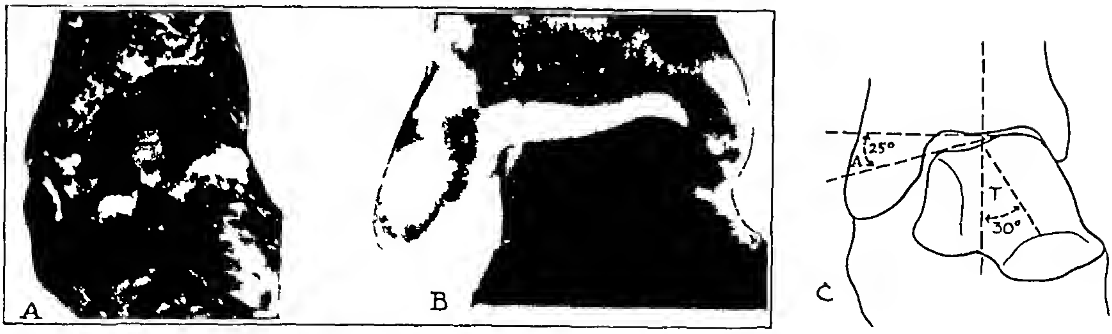

FIG 1
Anterior talofibular ligament has been cut and foot is inverted in equinus

various components of the lateral ligaments in maintaining talotibial stability Most authors state that the calcaneofibular ligament is the most important, that it ruptures most commonly, giving the greatest degree of instability [1,2,3,5] Pennal, in the illustrations of his article, showed that cutting the calcaneofibular ligament of a fresh cadaver resulted in about 4 degrees of ankle instability by roentgenogram, but that cutting the anterior talofibular ligament gave 12 degrees As a corollary, we wonder in what position the foot should be inverted (at 90 degrees or in equinus) to show maximum ankle instability

EXPERIMENTAL FINDINGS

In order to visualize the mechanism of inversion injuries resulting in ligamentous

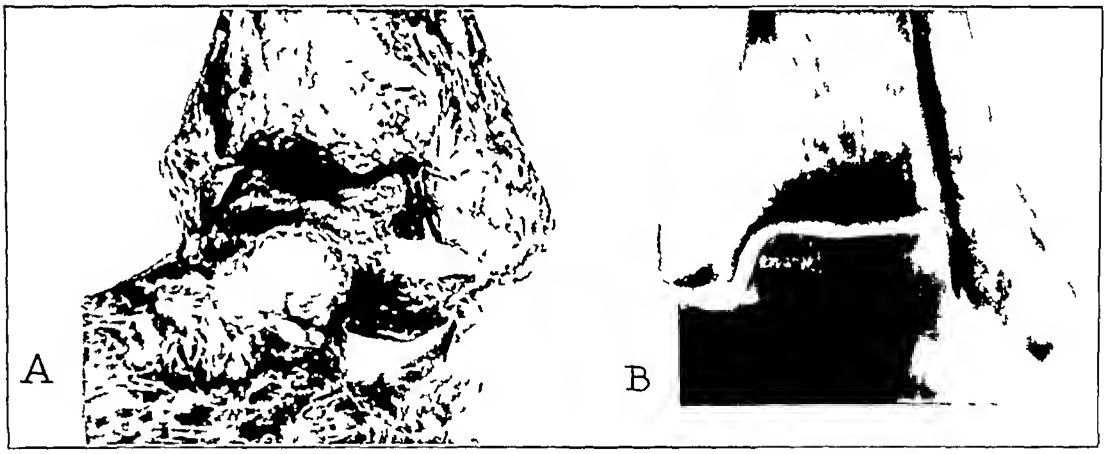

FIG 5-A
Calcaneofibular ligament has been cut and foot has been inverted at 90 degrees Note tibiotalar stability, increase of subtalar motion

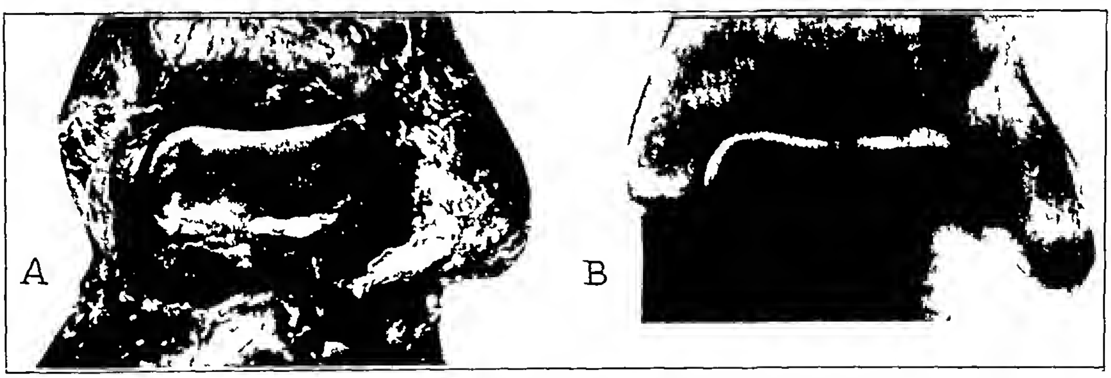

FIG 5-B
Same specimen as shown in Fig 5-A, in equinus,

FIG 6

Anterior talofibular and calcaneofibular ligaments have been cut
A Note gross instability, shown in photograph
B Inversion, with foot at 90 degrees *C* Inversion, with foot in equinus

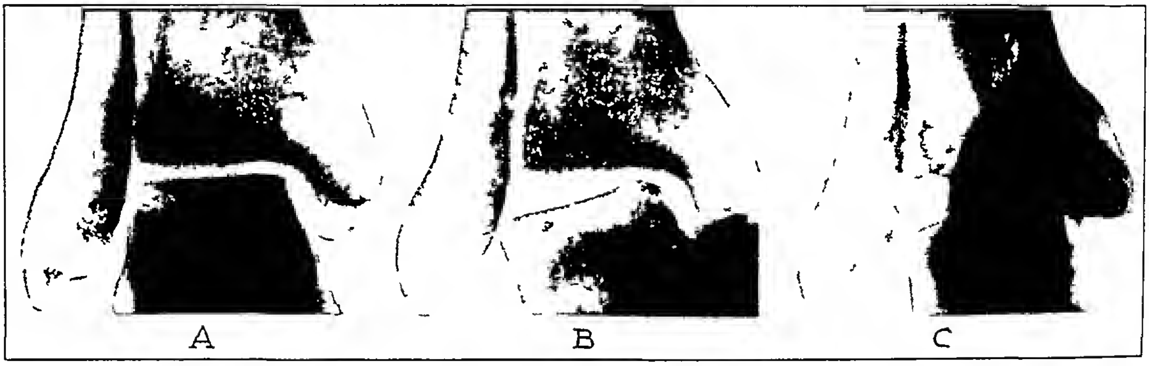

FIG 7

Posterior talofibular and calcaneofibular ligaments have been cut
Inversion, with foot *A*, in equinus, *B*, at 90 degrees, and *C*, in hyperextension

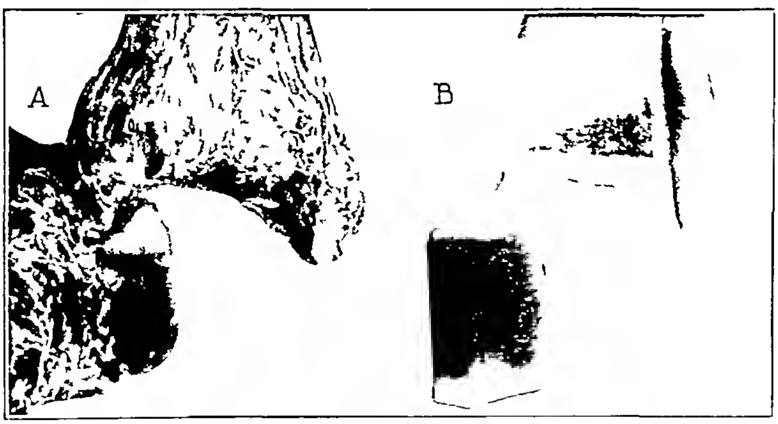

FIG 8

All three ligaments have been cut

damage, and to assess the importance of a given ligament in the maintenance of talotibial stability, seven preserved ankles were stripped of their soft parts, the collateral ligaments being retained Observations were made first of the course of the ligaments in varying degrees of plantar-flexion and dorsiflexion, and then of the effect of cutting the ligaments in various combinations on ankle stability in equinus, at 90 degrees, in dorsiflexion, and in extreme dorsiflexion Photographs and roentgenograms were taken

With the foot at an angle of 90 degrees with the leg, the calcaneofibular ligament is perpendicular and the anterior talofibular ligament is parallel to the long axis of the talus Therefore, inversion in this position results in strain on the calcaneofibular ligament (Fig 1)

However, most ankle inversions occur with the foot in plantar-flexion during forward propulsion, or when the patient is wearing high heels With the foot in equinus, the calcaneofibular ligament is parallel and the anterior talofibular ligament is perpendicular to the long axis of the talus (Fig 2) From this, it can be deduced that the anterior talofibular

ligament is the one most commonly injured This is also true clinically In almost all of the fifty-one cases studied, tenderness was present over the anterior talofibular ligament

After the anterior talofibular ligament has been cut, the ankle is relatively stable at 90 degrees since the wide portion of the talus is engaged in the ankle mortise (Fig 3) With the foot in equinus, the ankle is less stable (Fig 4) In addition to the instability in the long axis of the talus, there is also instability around the vertical axis of the talus

When the calcaneofibular ligament has been cut and the ankle has been inverted at 90 degrees, there is increased motion in the subtalar joint, but the tibiotalar relationships remain practically the same (5 degrees) (Fig 5-A) The ankle is stable in equinus (Fig 5-B)

With both the calcaneofibular and the anterior talofibular ligaments cut, there is marked instability both in the weight-bearing and in the long axis of the talus (Fig 6)

Cutting the posterior talofibular ligament permits extreme dorsiflexion, but the ankle remains stable With both the posterior talofibular and the calcaneofibular ligaments cut, even more dorsiflexion is possible At 90 degrees there is instability of about 10 degrees in the long axis of the talus, but the ankle is stable in equinus (Fig 7)

When all three ligaments have been cut, the ankle is grossly unstable (Fig 8)

From these experiments the author concludes that the anterior talofibular ligament is the most frequently ruptured and the most important component of the lateral ligaments of the ankle Inversion films should be taken in equinus, if the tenderness is anterior to the fibula, and at 90 degrees, if the tenderness is posterior to the fibula

SUMMARY AND CONCLUSIONS

1 In a series of fifty-one severely "sprained" ankles, twenty-three were shown to be spontaneously reduced and four to be recurrent subluxations of the ankle Seven of twenty-four stable ankles had persistent disability for as long as five months when treated by injection and strapping

2 By observing the course of the lateral ligaments and the effect on ankle stability of cutting them in various combinations, it is concluded that

A The anterior talofibular ligament is the important component of the fibular collateral ligament of the ankle

B Inversion films in severe ankle "sprains" should be taken with the foot in equinus, unless there is tenderness posterior to the fibula (which indicates injury to the posterior talofibular ligament) In this event the foot should be inverted with the ankle at 90 degrees

3 Unstable ankles should be immobilized in walking plaster for about six weeks and should then be strapped with elastoplast for an additional two or three weeks

NOTE The author wishes to thank William J Stewart, M D , and Edward L Compere, M D , for their helpful suggestions and criticism

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SOME OBSTETRICAL INJURIES TO THE LONG BONES

BY SPENCER T SNEDECOR, M D , AND HARRISON B WILSON, M D , HACKENSACK, NEW JERSEY

Trauma to the long bones of babies through the force of breech extraction is sufficiently common and serious to be of interest to the orthopaedic surgeon The series of eleven cases reported here demonstrate a distinct orthopaedic entity with its causative mechanism, pathological changes, and course of recovery

The long bones receive their greatest injury at the epiphyses, and by subperiosteal stripping of the tissues adjacent to them The authors, an orthopaedic surgeon and an obstetrician, conceive the mechanism of this injury to be the strong manual pull and torsion strain exerted on the lower limbs when a baby is delivered breech first [8, 10] The extraction force is often exaggerated by the urgency of the delivery and is likely to be carried out in a consistent straight line, which necessarily causes severe torsion on the lower extremities, as the body of the baby must rotate 45 degrees to come through the birth canal Under this strain the bone gives way at its weakest point, the epiphysis and the periosteum (and muscles) strip off down or up the diaphysis, as the case may be The greatest periosteal separation occurs at the epiphysis Within five to ten days a proliferative calcification takes place in the hemorrhage around the epiphyses or under the periosteum, and this becomes evident roentgenographically An appreciation of the whole concept will help in avoiding the confusion in diagnosis and prognosis which the authors experienced with their first cases

TABLE I

SUMMARY OF ELEVEN CASES

Babies born of primiparas	11
Breech presentation	5
Podalic version	6
Epiphyseal injuries	6
Periosteal stripping	7
Both epiphyseal injury and periosteal stripping	2
Sites of involvement	
Upper portion of humerus	1
Upper portion of femur	4
Lower portion of femur	7
Upper portion of tibia	1
Lower portion of tibia	2

A preliminary report of this phenomenon was made in 1935 [9] Once the entity had been appreciated, careful observation uncovered other instances from time to time During a period of twenty months, 160 babies who had had breech presentations were examined carefully In fifty consecutive breech deliveries on the ward service of the Hackensack Hospital, the infants were x-rayed on the seventh day, and in three cases (6 per cent) evidence of periosteal or epiphyseal hemorrhage was found An equal number of other babies had painful limbs with obvious soft-tissue injury, but no roentgenographic evidence of bone disturbance From this study it is apparent that this type of skeletal injury is relatively common in babies who have been forcefully extracted feet first, especially in the first-born (Table I)

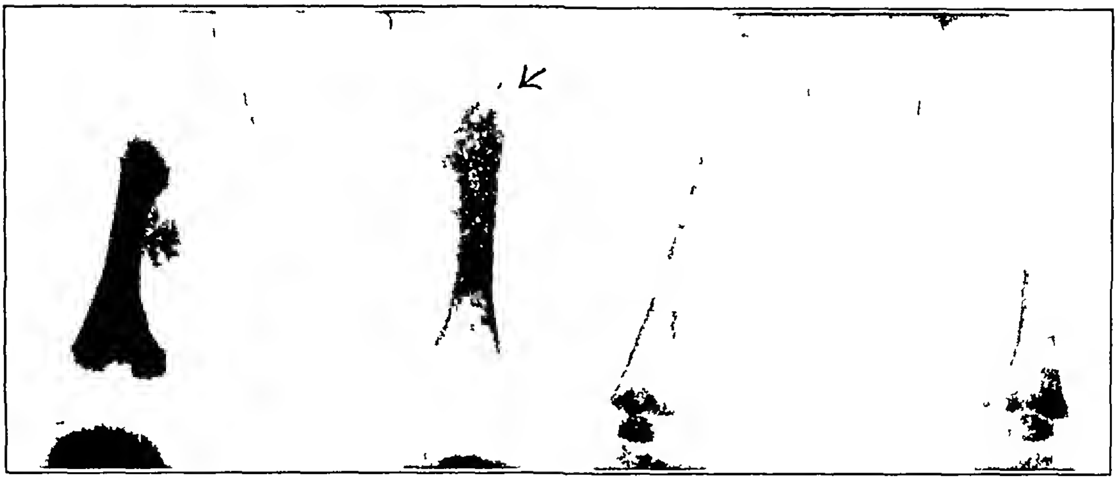

Fig 1-A Fig 1-B

Fig 1-A Case 1 Large deposit of calcium about capital epiphysis of femur, forty days after birth
Fig 1-B Resolution three months later

A review of the literature on birth injuries has disclosed frequent references to nerve palsies and obstetrical fractures A few notations on epiphyseal trauma have been found, but no mention of periosteal stripping Meier and Ruschenburg in Germany, Taverinier in France, Cantat and Peluffo in Uruguay, Rivarola in Argentina, and others have reported cases of obstetrical epiphyseal injuries Scaglietti, in a summarizing report from Putti's clinic in 1938, told of such injuries to the capital epiphysis of the humerus Other descriptions of separation of the lower epiphysis of the humerus, as well as of the upper and lower epiphyses of the femur, have been found in articles in the foreign literature Two single case reports on epiphyseal injuries, recently published in the United States [1,3], show that this type of obstetrical trauma is coming to be recognized in this country However, its occurrence as a relatively common complication of breech deliveries is worthy of special note, by both the obstetrician and the orthopaedic surgeon

The clinical picture is quite typical Tender swollen legs are observed the day after delivery Whenever the limbs are moved, the child cries with pain Roentgenograms

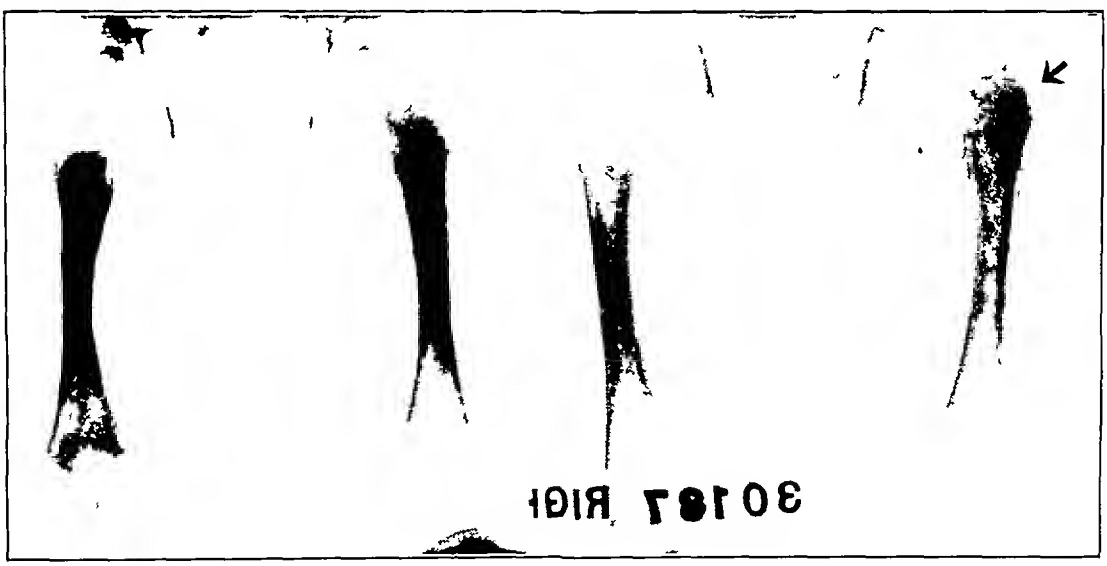

Fig 2-A Fig 2-B

Fig 2-A Case 2 Negative findings in roentgenogram taken five days after birth
Fig 2-B Four weeks after birth, large mass is seen about upper femoral epiphysis, as well as some periosteal thickening

on the second or third day have always been negative In those infants with simple soft-tissue hemorrhage, the condition clears rapidly, but many of the babies have suffered enough trauma to have more lasting bone effects Even as the acute physical discomfort subsides after a few days a deposition of calcium takes place in the hemorrhagic nidus, and by the seventh day the roentgenographic picture illustrates the more severe periosteal and epiphyseal changes

The significant roentgenographic characteristics of the lesion are dense shadows of calcification around the epiphysis, if separation or torsion has occurred there, and subperiosteally, if the muscles and periosteum have been pulled away from the bone In three instances both sites became calcified (Cases 1, 8, and 11), indicating extensive involvement of both The roentgenograms of other cases in the series demonstrate stripping along the shafts of both the femur and the tibia In one instance the capital epiphysis of the humerus was involved, following a delivery with the arm in an extended position beside the head

So far, eleven cases have been recorded in this series, but it seems certain that if babies with breech presentation, born of primiparas, are carefully checked with roent-

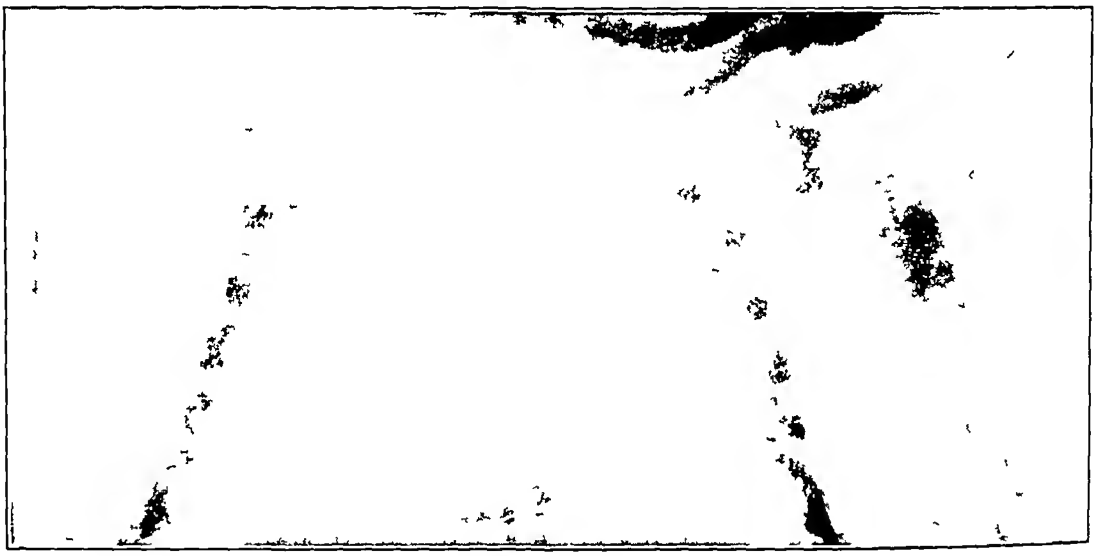

Fig 3-A

Case 3 Calcium deposit at capital epiphysis of humerus nine days after birth

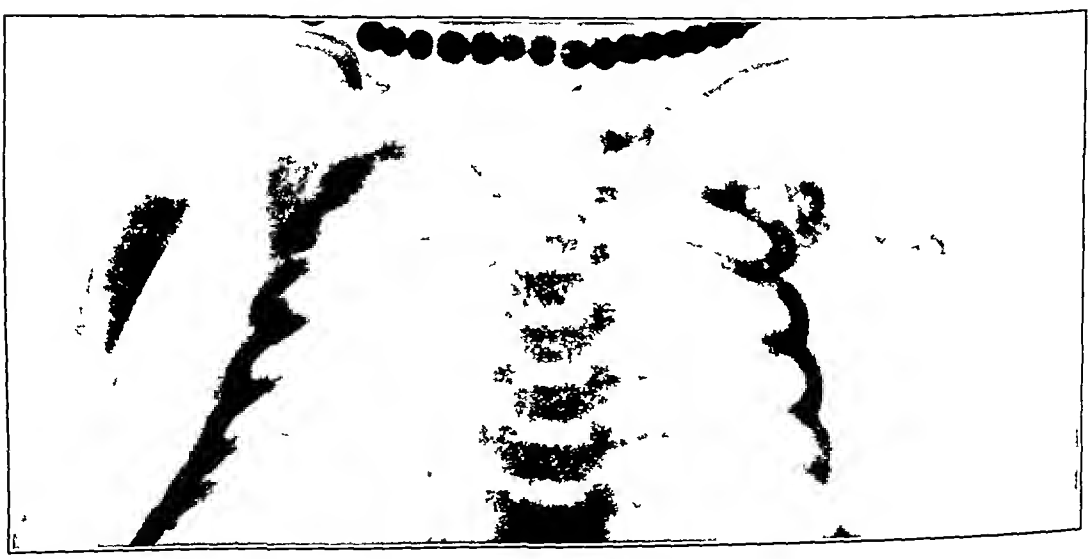

Fig 3-B

Increased calcium five days later

genograms taken on the seventh day, this injury will be found to be relatively common

The prognosis following the injury has been uniformly good, with one exception Within two or three weeks, all of the clinical symptoms disappear and the roentgenograms show a diminution in the periosteal thickening Within three or four months, roentgenograms of the bone show practically complete resorption to a normal condition In the one exception (Case 8), the lower epiphysis of the femur began to show distortion after four months Later roentgenograms of this infant revealed a permanent bowing of the shaft for the first six years, an incidental fracture occurred when she fell from a crib at the age of one year This child did not have a limp and was not handicapped in her activities but it seemed clear that the lower femoral epiphysis had been permanently injured or displaced at birth

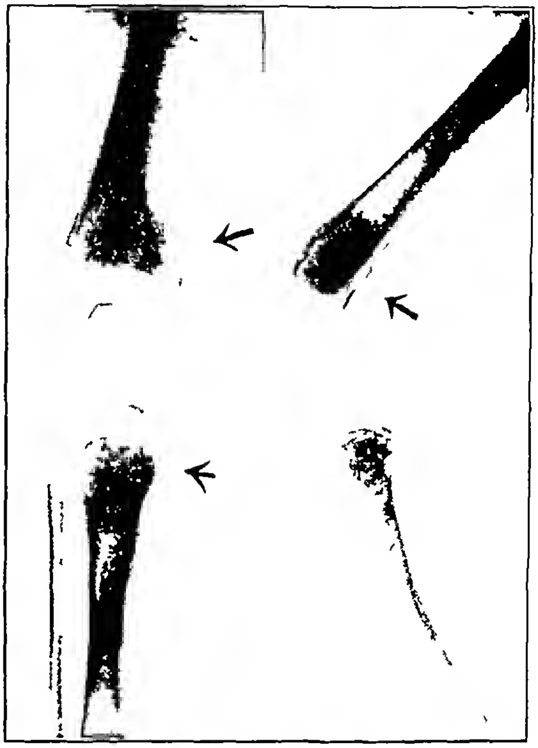

Fig 4-A Fig 4-B

Fig 4-A and Fig 4-B Case 4 Periosteal calcification in right and left femora and upper portion of right tibia on the tenth day is shown Some epiphyseal injury probably was present

ABSTRACTS OF CASE HISTORIES

Case 1 Baby M was born of a primipara, delivery was by podalic version and breech extraction Trouble with the lower extremity was apparently unnoticed until five weeks after birth The limb was held in a flexed position and motion was painful The first roentgenogram (Fig 1-A), forty days after birth, showed a large mass of periosteal new-bone formation about the head of the femur Three months later (Fig 1-B) nearly complete resolution had occurred

Case 2 Baby A, who weighed six pounds and

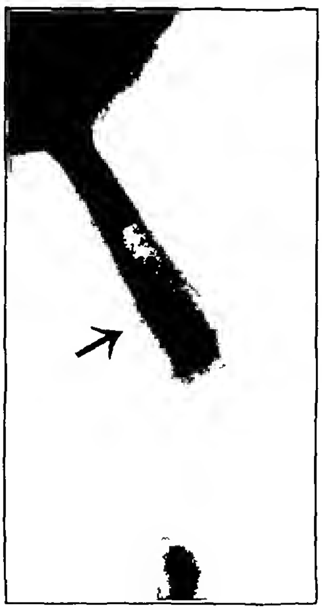

Fig 5

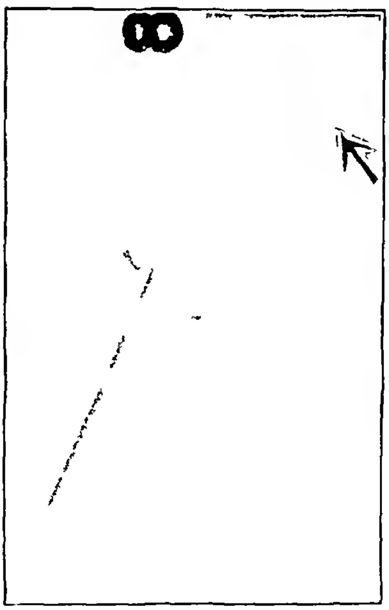

Fig 6

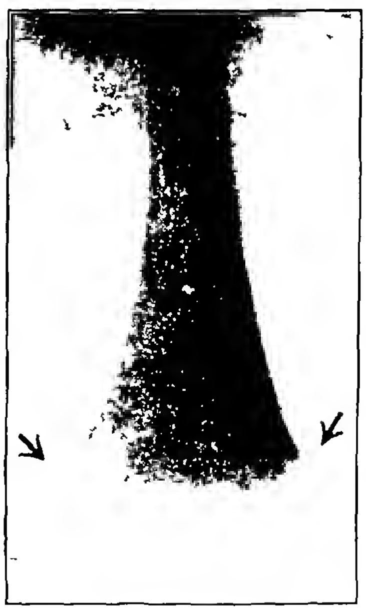

Fig 7

Fig 5 Case 5 Roentgenogram on eighth day shows periosteal stripping of lower half of femur
Fig 6 Case 6 Calcium deposit on medial aspect of upper portion of femur on seventh day
Fig 7 Case 7 Thickening of periosteum of lower portion of femur with periosteal horns, on ninth day

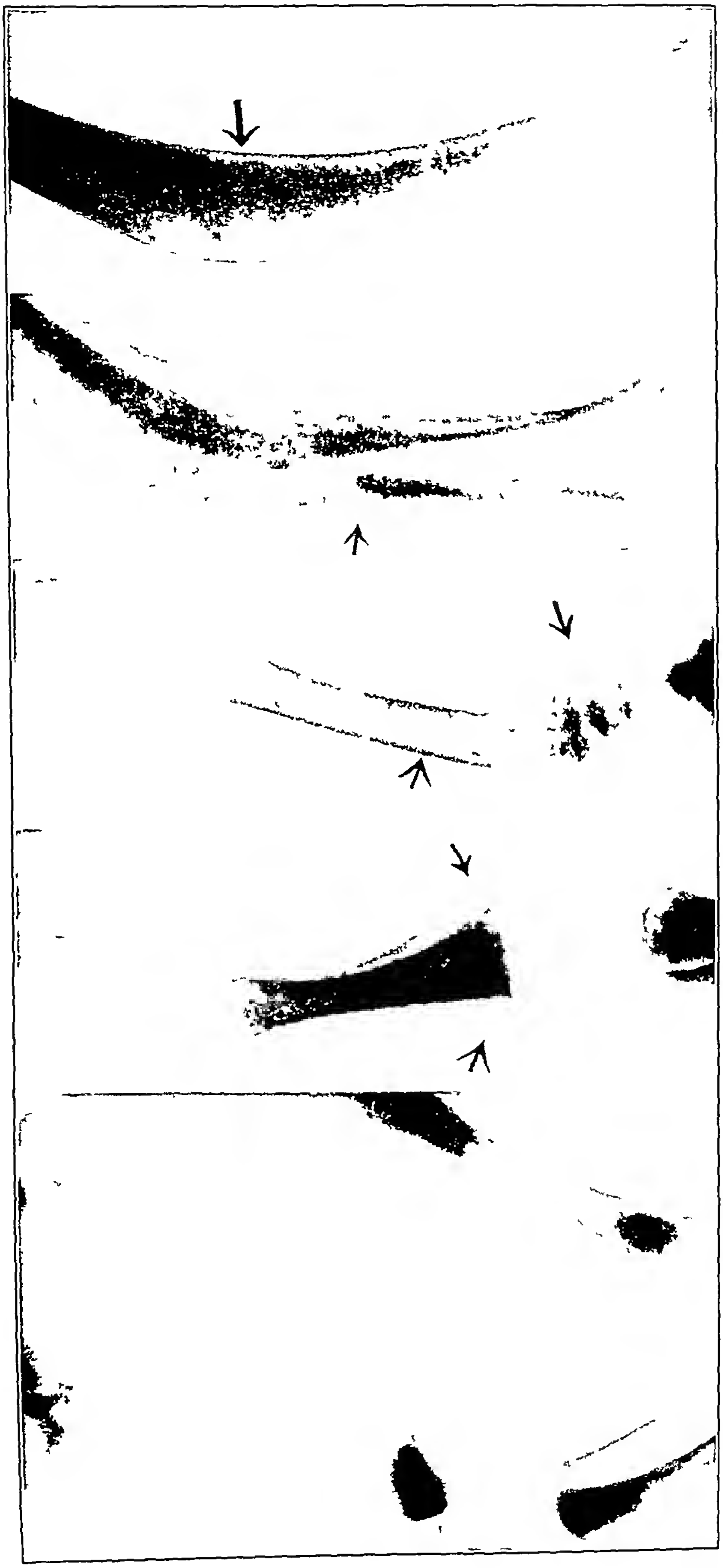

Fig 8-A Fig 8-B Fig 8-C Fig 8-D Fig 8-E

Fig 8-A Case 8 Both femora negative on third day
Fig 8-B Dense subperiosteal calcium deposit may be seen along lower half of femur and around epiphysis, on twelfth day
Fig 8-C Resorption after four months, with beginning distortion of epiphysis
Fig 8-D At one year, incidental fracture occurred through bowed femur Fig 8-E Bowing of femur still present at age of six years

twelve ounces, was born of a primipara, there was a difficult delivery by podalic version and breech extraction The day after birth the infant's left lower extremity and foot were swollen, discolored, and painful on motion The first roentgenogram (Fig 2-A), five days after birth, was negative Four weeks after birth (Fig 2-B) a large amount of calcification was present around the head of the femur

CASE 3 Baby H, who weighed eight pounds and fifteen ounces, was born of a primipara, with difficult delivery by podalic version and breech extraction At delivery the left arm was in extension alongside the head The injury to the left shoulder and arm was noticed immediately The arm was limp and there was some wrist-drop The first roentgenogram (Fig 3-A), nine days after birth, showed periosteal proliferation around the upper epiphysis of the left humeral shaft Five days later (Fig 3-B) there was further calcification of the same area

CASE 4 Baby M, who weighed eight pounds and five ounces, was born of a primipara, by breech presentation and delivery The right lower extremity appeared swollen, the foot was bruised, and the infant held her limb in an awkward position The left lower extremity was also bruised and appeared very painful A roentgenogram, taken when the baby was two days old, was negative When the child was ten days old (Figs 4-A and 4-B) periosteal thickening was apparent in the lower half of the shafts of both femora and in the upper end of the right tibia

CASE 5 Baby M, who weighed six pounds and eight ounces, was born of a primipara, by breech presentation and extraction The left lower extremity appeared swollen from the knee to the hip, and was painful and tender to the touch Roentgenograms on the eighth day (Fig 5) showed periosteal stripping of the lower end of the femur

CASE 6 Baby K was born of a primipara, by breech presentation and extraction The baby had bruises on both lower extremities On the seventh day (Fig 6) bone proliferation was seen at the proximal femoral epiphysis Later roentgenograms showed complete absorption

CASE 7 Baby W, who weighed six pounds and three and one-half ounces, was born by breech presentation and extraction The baby held the lower extremities flexed in a peculiar manner, the right limb seemed swollen Roentgenograms (Fig 7), taken when the infant was nine days old, showed periosteal thickening and projections along the lower half of the left femur

CASE 8 Baby S, who weighed six pounds and fifteen ounces, was born by difficult podalic version and breech extraction The right lower extremity seemed partially paralyzed and motion caused pain Three days after birth, a roentgenogram (Fig 8-A) was negative On the twelfth day (Fig 8-B) extensive subperiosteal calcification was seen along the whole femoral shaft and around the lower epiphysis After four months, roentgenograms (Fig 8-C) showed resorption of the periosteal thickening, but early changes in the epiphysis A fracture of the femur when the child was one year of age (Fig 8-D) illustrated the marked anterior bowing At the age of six years (Fig 8-E) this bowing was still present

CASE 9 Baby W was born of a primipara, by breech presentation and extraction No injury was noted at birth After six weeks it was found that the baby kept his left lower extremity folded under the right and cried when his left limb was moved Roentgenograms at six weeks showed marked proliferation around the head of the left femur and periosteal thickening down the shaft Three weeks later a denser calcium deposit was visible

CASE 10 Baby O was born of a primipara, by breech presentation and extraction Roentgenograms showed periosteal stripping and calcification at the lower ends of both the right femur and the right tibia

CASE 11 Baby S was born of a primipara, delivery was by podalic version and breech extraction After birth the left foot appeared bruised On the ninth day, roentgenograms showed ossifying periosteal hemorrhage of the lower third of the shafts of both the femur and the tibia

CONCLUSIONS

1 Injuries to the long bones are relatively common complications of breech deliveries, especially in babies born to primiparas, and can be recognized as a definite entity

2 Roentgenographic evidence of calcification in the hemorrhage is found on the fifth to seventh day

3 These injuries follow a pattern of epiphyseal separation, periosteal stripping, and a combination of both

4 According to the authors' concept, the mechanism of such injuries may be decreased by the use of less force, if possible, and by careful turning of the lower extremities to follow the rotation of the body during extraction

5 The prognosis is relatively good for spontaneous recovery without specific treatment in most instances, but permanent epiphyseal growth changes may take place occasionally

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DISCUSSION

CONGENITAL DYSPLASIA OF THE HIP JOINT

(Continued from page 372)

In reply to his question as to how I know there are many causes of intra-uterine dislocation, I should not have used the word *many* I should have said *several* When we examine children with dislocated hips, we occasionally find a child who has spina bifida and paralysis of the extremity We know the mechanism of pathological paralytic dislocation Occasionally we see a child who has clinical evidence of muscular dystrophy with degenerative fibrosis and contractures of muscles, as in myodystrophia foetalis or arthrogryposis multiplex congenita We know that such contractures may displace the hip joint If a child is born with one foot around the neck, with the knee hyperextended, and the hip joint in the position of flexion and adduction or of instability, it is only logical to assume that the hip was displaced because of the intra-uterine breech position It is my opinion, however, that the great majority of congenital displacements of the hip are on the basis of genetic or biomechanical dysplasia of the hip joint, alone or in combination Most displacements during infancy are subluxations and not dislocations The terms preluxation and subluxation are synonymous I believe that all patients with congenital dislocation of the hip joint secondary to congenital dysplasia have gradually passed through the phase of subluxation,—some during intra-uterine life, but the majority during early infancy, when dislocation could have been prevented by early recognition and treatment

MORTISED TRANSFACET BONE BLOCK FOR LUMBOSACRAL FUSION*

BY EARL D. McBRIDE, M.D., OKLAHOMA CITY, OKLAHOMA

For many years the orthopaedic surgeon has performed fusion as a dependable method of treating intractable low-back pain. Attention was sharply focused on the importance of the lumbosacral region through the discovery of the herniated intervertebral-disc syndrome by Mixter and Barr. It has now become necessary to re-evaluate the indications for lumbosacral fusion and to redetermine the end results.

The exceedingly prompt relief from acute pain obtained by operation for a herniated disc did not mask for long the fact that the pathological manifestations associated with herniation of the intervertebral disc are fundamentally structural deficiencies and only secondarily neurological entities. A more appropriate term would be "disc disease". Because the neurological phenomena are more obvious, a tendency exists to ascribe all low-back symptoms to the disc. Removal of the disc only has received too much credit, as stressed by Farrell and MacCracken. At present the literature contains many analyses of results of disc operations, with little or no consideration being given to the mechanics of associated structural disorders. It is the author's practice to expose freely and to investigate the posterior facets and foramina, bilaterally, in all disc operations. In 100 cases in which the facets and laminae on both sides were exposed at the time of disc operation, 46 per cent. showed mild structural deficiency and 35 per cent. showed marked pathological changes, such as telescoping of facets due to settling down of the intervertebral space, unexpected anomalies, senescent or osteo-arthritic changes, and obstructions along the course of the nerve roots. A large proportion of these abnormalities are missed if the roentgenogram alone is depended upon to reveal them.

The favorable end results in patients with disc lesions of long standing which have not been operated upon, and also in many cases in which operation has been done but not fusion, are probably due to stabilization from fibrous ankylosis. Slow, gradual narrowing of the intervertebral space is apt to follow removal of the disc. If this fibrous-tissue stabilization gives way, low-back pain may return. Bony fusion is the only way to counteract the predisposition of the lumbosacral structures toward progressive degenerative changes.

THE PRINCIPLE OF FUSION

Present Status of Opinion as to Value

Many variations and conflicting opinions exist concerning the advisability of fusion in the lumbosacral region. Briefly, the following assertions may be made:

1. Stabilization by fusion of the structurally affected lumbosacral joint is a sound, dependable procedure. It still may be said that a well-fused joint ceases to be painful. However, fusion is not a substitute for removal of the herniated disc or other source of nerve-root irritation.

2. Surgical intervention for the relief of pain due to posterior herniation of disc tissue has focused attention upon the frequency of a specific lesion in the lumbosacral region.

3. Whether or not to fuse in cases of herniation of the disc is debatable. Although enthusiasm for removal of the herniated disc has temporarily overshadowed the importance of structural disorders, fusion to prevent residual symptoms or relapse is justified to an extent greater than the neurological findings alone would indicate.

4. The numerous variations in technique of fusion operations in the lumbosacral region indicate dissatisfaction with results. Statistics have revealed a higher percentage of relapse with pseudarthrosis than is generally realized.

*Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 29, 1948.

5 Little new has been added to the technique of surgical fusion Many methods have been described, but practically all are based upon the original method of Hibbs or Albee

6 Interbody fusion by bone blocks in the intervertebral space, by either the abdominal or laminal approach, has been tried by Lane and Moore with some favorable results

7 One new principle which has gradually gained recognition is that of distraction by propping apart the laminae or spinous processes to lessen foraminal impingement and to give immediate interlaminal support and stabilization

8 Long periods of plaster-cast immobilization or bed confinement are being avoided

9 A quick method of immobilization by transfixion screws in the facets, as recommended by King and others, is being tried The reports are not convincing

10 Metallic fixation by plating or wiring has been used in conjunction with bone transplants

11 Iliac bone is rapidly replacing tibial bone, when transplants are used

Recent Concept

In the light of present knowledge, surgical procedures in the lumbosacral region must be carried out with more specific intentions Arthrodesis is not a substitute for removal of a herniated disc, but, if all local pathological factors are investigated, more fusions will be done supplemental to removal of a disc More consideration is now given the taut stationary nerve roots These nerve cables are threaded through passageways that might require bone decompression If the smooth gliding surfaces of these nerve trunks are compressed or bound by adhesions, they will not respond to vertebral reactions from body shock, stress, or strain, even after fusion has been established The great majority of end results following simple removal of the disc may be classified as good, but, in a joint defective enough to cause extrusion of a disc, further degenerative changes can develop In this respect the situation is not unlike that found in inguinal hernia One certainly would not remove the sac without carrying out the reparative procedure

Improved Technique

Time has proved that successful fusion in the lumbosacral region depends greatly upon good engineering The conventional bone-chip method of Hibbs or the bone-transplant method of Albee is more adaptable to the thoracic spine in children, for which these methods were originally recommended Even though extremely heavy grafts and extensive bone chipping, of mutilating proportions in some cases, have been applied with many variations, absorption, followed by pseudarthrosis of the supposedly fused lumbar areas, has too often been the result In a recent study, Cleveland, Bosworth, and Thompson have noted an incidence of pseudarthrosis as high as 20 per cent in 647 fusions over a period of twenty years This included all fusions extending from the third or fourth lumbar segment to the sacrum In the lumbosacral joint, the incidence of pseudarthrosis was 3 4 per cent This should be a stimulus for others to compare their end results and to seek improved methods

The improvements needed in fusion of the lumbosacral area might be summarized as follows

1 A more certain method of fusion, especially above the fifth lumbar body,

2 Development of a method providing earlier mobilization after operation,

3 Simplification of the technique of fusion and lessening of the time and risk when this procedure is done after a disc operation

Principle of Interlaminal Distraction

The innovation of interlaminal distraction to decrease intraforaminal compression has proved valuable It is usually accomplished by propping apart the spinous processes

In many cases the collapse of the intervertebral space is found to have caused telescoping of the facets, to the extent that the inferior borders of the inferior articular processes rest on the adjacent laminae

Williams first recognized the principle of distraction in his "conservative treatment" of lumbosacral disabilities, by maintaining a posture of flexion to correct the intervertebral subluxation and the narrowing of the foramina Breck and Basom introduced the concept of maintaining fixed surgical distraction through the use of interspinous bone

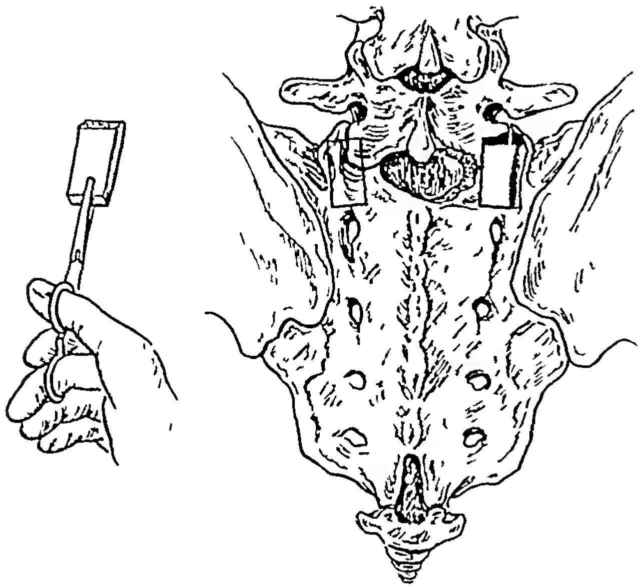

Fig 1-A

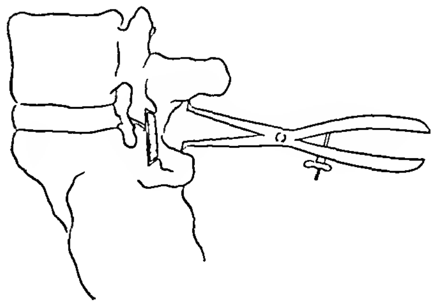

Fig 1-B

The transfacet bone block, as a dovetailed graft, impacted under distraction into a rectangular mortise, extends from the laminae below to the facets above, to form an interlaminal supporting strut
Fig 1-A Anteroposterior aspect
Fig 1-B Lateral aspect

blocks Gibson devised the clothespin or fish-tail graft, Bosworth used a similar graft to lock the spinous processes in distraction Moore has termed still another similar procedure the self-locking graft

THE MORTISED TRANSFACET BONE BLOCK

It is frequently stated that fusion would be done more often after disc operations if a simpler method were available The procedure described here is suggested with the aim of simplicity

The most strategic point for elimination of intervertebral motion is at the facet articulations, as stressed by Meyerding Their surfaces are comparatively large and the center of gravity is more nearly at this point The articular processes are strong and sturdy enough to provide an excavated bed and abutments for the firm implantation of a substantial block of bone When accurately countersunk across the facets (Figs 1-A and 1-B), such a graft will render immediate support and stabilization, and will eventually produce an interlocking bony fusion An operative technique devised for such a mechanical objective has been employed in 135 cases with gratifying results

Technique

The patient lies prone on an especially devised convex frame (Fig 3), two padded saddle bars support each side of the pelvis, leaving the abdomen free from pressure The spinous processes and laminae on both sides are thoroughly denuded and the soft tissues are widely retracted, to permit free visualization of the facet articulations of the involved region

Attention is directed to a small but definite anatomical structure, not described in the anatomy texts, consisting of a ball of fat that fills the interlaminal fossa It borders t ligamentum flavum medially and is attached laterally to the fascia over the face

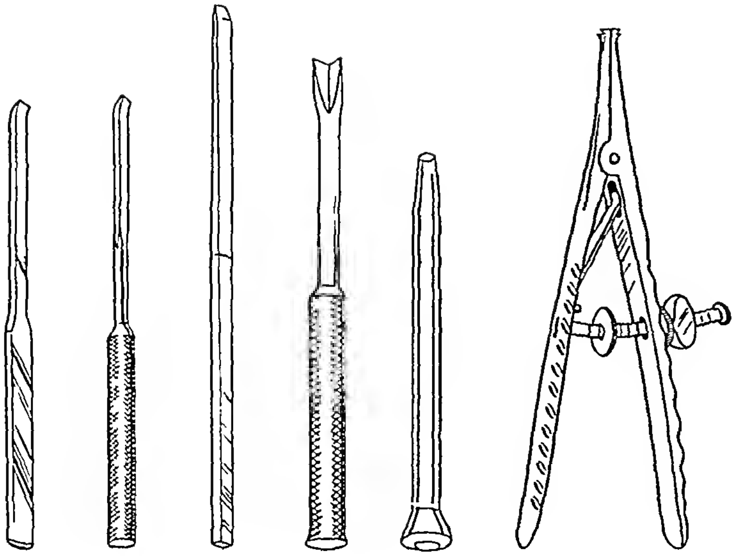

FIG 2

Special instruments used in accurately countersinking the transfacet bone block

receive a small terminal artery and nerve from the lateral margin of the superior articular process of the vertebra below No doubt this is the cause of the trouble-some bleeding which Hibbs originally mentioned in describing his fusion operation It is of advantage to coagulate this vessel and to remove the entire fat pad before removal of the ligamentum flavum

If the disc is to be explored, this part of the operation is completed prior to the fusion Whether the disc operation is done or not the ligamentum flavum and all fibrous tissue are thoroughly cleaned from the bone Spreaders are then applied between the spinous processes to correct any telescoping of the facets that may have occurred from collapse of the intervertebral space

A rectangular excavation is made lengthwise in the articular processes, crossing the facets above and extending into the laminae below The excavation should be about one-fourth to three-eighths of an inch wide, one-eighth to three-sixteenths of an inch deep, and from one-half to three-quarters of an inch in length The upper end should be so located as to include about equal parts of the articular processes A right-angled osteotome, with each blade one-quarter of an inch wide, is used to make square corners, although an ordinary thin osteotome, one-quarter-inch wide, may be employed Starting at a point about three-sixteenths to one-quarter of an inch above the inferior border of the facets, the first cut is made into the articular processes until the osteotome extends through the facet of the inferior articular process of the vertebra above The lateral margins are then cut and accurately squared The upper end of the excavation is undermined and all cartilage surfaces are removed Care should be used not to break the outer ledge of the superior articular process of the lower lumbar vertebrae Likewise, it is important to have a substantial medial wall to the excavation, otherwise the graft will shift sidewise

FIG 3

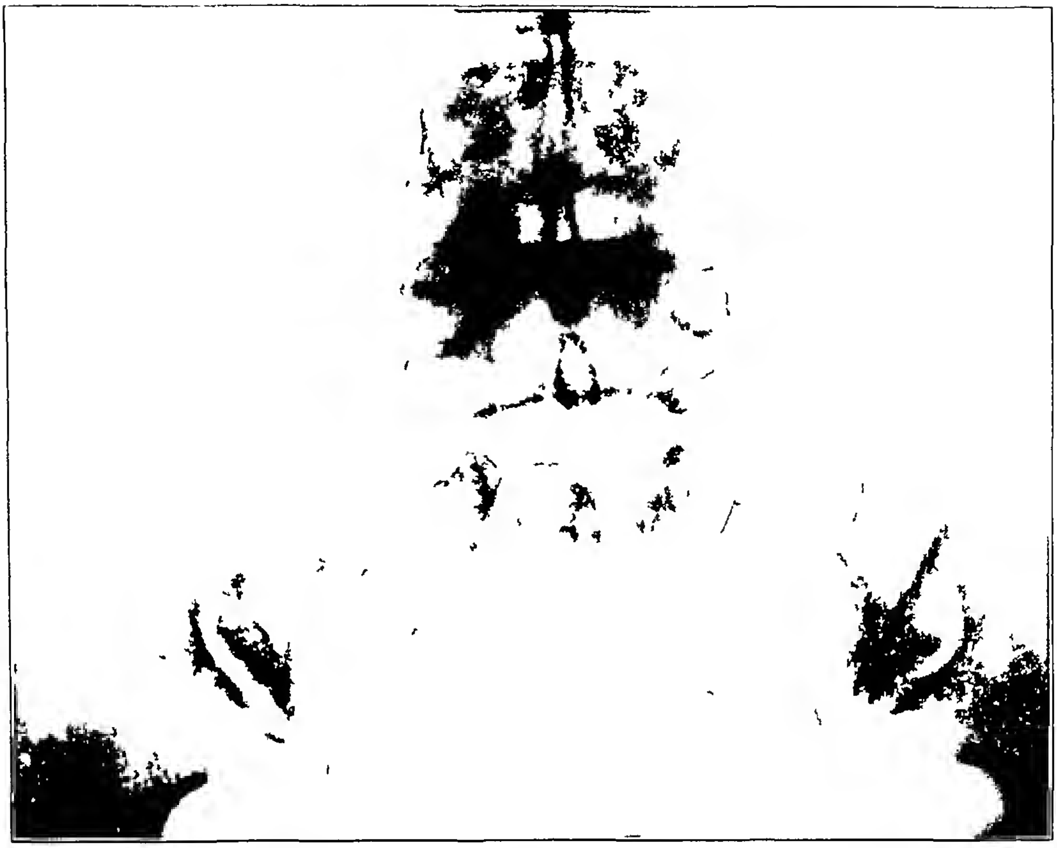

Fig 4

Tantalum wire used to demonstrate roentgenographically the location of the bone blocks

The lower end of the excavation is located on the lamina below, about one-half inch lateral to the base of the spinous process The depth may be from one-eighth to three-sixteenths of an inch, but caution should be used not to penetrate the wall of the neural canal The floor of the excavation, which consists largely of the articular facet of the superior process of the lower vertebra, is leveled by a thin, quarter-inch osteotome, slightly curved on the tip The upper and lower ends of the excavation are undercut to the extent that a beveled bone block, about three-sixteenths of an inch thick, can be countersunk in dovetailed fashion to lock the graft into the depth of the cavity as the interlaminal spreaders are removed Additional bone chips may be wedged about the articulations, or other additions may be made as desired The bone-block grafts are taken preferably from the spinous processes, each process will furnish material for two blocks The prominence at the posterior spine of the ilium may be used if thicker, heavier bone is desired Two qualifications are necessary for the bone blocks

1 They must be long enough to be wedged firmly in place by the driving force of a carpenter's punch

2 They must be strong enough to withstand the pressure when the distraction force between the vertebrae is released

To wedge the graft into the excavation, the interlaminal spreaders are applied The upper end of the block is first pressed into place Then with a punch, the other end is tapped firmly and impacted into position The transfacet bone blocks are wedged into place on each side before the distraction produced by the spreaders is removed or changed If the graft is not impacted firmly and does not lock in place, it should be removed and made to fit more accurately When the spreaders have been removed, the grafts are tested for firm impaction and the wound is closed, after the operator has made certain that all blood

oozing has stopped The patient is placed in bed on his back with no external immobilization

In spondylolisthesis, the cartilaginous material in the pars interarticularis is removed thoroughly, and the bone block is made long enough to insert well into the cavity The laminae are left intact Immediate immobilization is the result Additional bone chips and grafts may be used if further assurance of fusion is necessary

In four cases of scoliosis, the blocks have been applied on the concave side for correction of the curve With one-quarter inch of spread on eight interlaminal spaces, a positive correction of two inches is obtained

The patient is allowed bathroom privileges on the tenth or twelfth day On the fourteenth day, a model is made for a low-back corset type of brace, and a plaster jacket is applied This jacket is exchanged for the brace about the fortieth day after the operation, when light work is permitted Hard manual labor, such as riding a tractor or heavy lifting, is not permitted for four months A number of patients have disobeyed this rule, however, with no apparent harm

RESULTS

In the 135 cases in which fusion was achieved by this method, there have been no deaths or serious complications Abdominal distress, mild or severe, has occurred occasionally, and catheterization has been necessary for the first day or two after operation in about 20 per cent of the cases Most of these complications occurred when the fourth and fifth lumbar interspaces, as well as the lumbosacral joints, were fused Most patients

Fig 5-A Fig 5-B

Biplane roentgenograms following transfacet bone-block fusion of the fourth and fifth lumbar vertebrae

Fig 5-A Forced flexion Fig 5-B Forced extension

Fig. 5-C
Forced lateral bending to the right

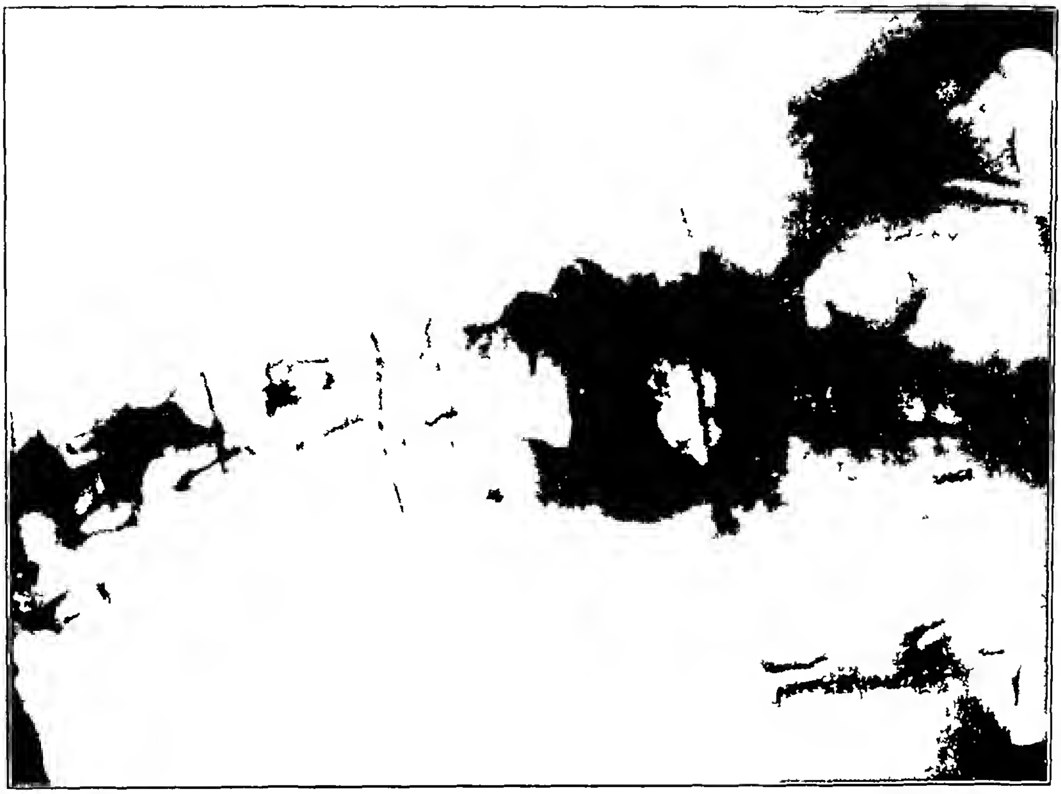

Fig. 5-D
Forced lateral bending to the left

TABLE I

EVIDENCE OF PSEUDARTHROSIS IN FORTY-ONE CASES, AS DETERMINED BY ROENTGENOGRAMS IN FORCED LATERAL AND FORWARD BENDING, TAKEN AFTER SIX MONTHS TO TWO YEARS

Diagnosis	No of Cases	Area Fused		Cases Showing Possible Pseudarthrosis by X-ray	
		Fifth Lumbar and First Sacral Only	Fourth and Fifth Lumbar and First Sacral	Fifth Lumbar and First Sacral	Fourth and Fifth Lumbar
Herniated disc	31	15	16	1	4
Spondylolisthesis	3	0	3	0	0
Collapsed narrow joint	2	2	0	0	0
Other anomaly	2	0	2	0	0
Osteo-arthritis	3	0	3	0	0
Totals	41	17	24	1	4

experience a sense of stability by the third or fourth day Undue pain following operation is rare, but, when it does occur, it is usually due to a hematoma In no case could it be determined that the nerve was affected by the excavation into the articular processes or by the trauma of inserting the bone block

In one case, recurrence of symptoms was sufficiently severe to justify reoperation The lower margins of the bone block were fused, the upper margins were not Various methods have been tried to demonstrate more clearly whether or not fusion takes place Tantalum wire was passed tightly around the edges of the bone block in a few cases, and the ends were fastened by twisting The wire localized the bone block in the postoperative roentgenograms (Fig 4) Otherwise the graft is not discernible, even in an oblique view

Seventy-four cases were followed by roentgenograms taken with the patient in forced anteroposterior bending, a method described by Gianturco Since Cleveland, Bosworth, and Thompson described their "biplane roentgenographic test", follow-up roentgenograms have been taken in both the lateral and the anteroposterior views of forced bending (Figs 5-A to 5-D) In the first series, only 11 1 per cent showed the presence of pseudarthrosis in the fourth and fifth lumbar segments, and 2 per cent in the fifth lumbar and first sacral region An analysis of forty-one cases tested by biplane roentgenograms is found in Table I These roentgenograms were taken at the end of six months and after one year or more

Pseudarthrosis, as demonstrated by biplane roentgenograms, was found in four cases with fusion of the fourth and fifth lumbar vertebrae, while the same roentgenographic technique seemed to have indicated that solid stabilization occurred in all instances in the lumbosacral joint Fusion has depended almost solely upon the wedged bone blocks, occasionally a few bone chips were added about the facets There are no contra-indications to any additional measures for reassurance of fusion, however, they require time and induce greater risk It is thought that the simple bone-block procedure is entirely adequate in the lumbosacral joint Fusion of the fourth and fifth lumbar vertebrae seems less certain Here additional bone chips packed about the denuded facet articulations offer greater security

SUMMARY

Lumbosacral fusion must be considered in light of the newer concepts developed through surgical treatment of herniated intervertebral discs Structural faults must be re-evaluated Stabilization by fusion is still the treatment of choice in lumbosacral instability, irrespective of the spectacular results obtained after removal of the disc without

fusion Pseudarthrosis, especially of the fourth and fifth lumbar segments, has been found frequently after the regular types of fusion, and a special technique is necessary

The technique described for accurately impacting a mortised transfacet bone block under interlaminal distraction has the following advantages

1 The period of confinement in bed is increased very little over that required for simple removal of a herniated disc

2 The fusion technique adds thirty minutes or less to the time involved in removing a herniated disc

3 There is a minimum amount of mutilation of the spinal structures

4 The articular facets are fused, which is of mechanical advantage

5 The bone block rigidly stabilizes interlaminal motion, immediately after being countersunk into position

6 Extension of the spine after operation locks the bone grafts firmly into position

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DISCUSSION

Dr David M Bosworth, New York, N Y In June 1947, Dr Cleveland, Dr Thompson, and I reported the incidence of pseudarthrosis in our series of lumbosacral spine fusions Comparable reports by other authors are possible only through the presentation of a similar number of cases and similar roentgenographic criteria of fusion (superimposable roentgenograms taken at the extremes of bending in two planes) It does not avail to emphasize the high incidence of pseudarthrosis in the past as a standard of comparison for a new technique of fusion, unless comparable evidence of fusion and pseudarthrosis is presented in support of the new technique

The development of pseudarthrosis after lumbosacral fusion has not been discouraging Some pseudarthroses are always likely to occur, but the percentage has gradually decreased over the years as new surgical means have been employed, based on better understanding of the basic factors of bone growth and repair Of some 650 cases of lumbosacral fusion reported by us, about 3 per cent of pseudarthrosis developed when

(Continued on page 399)

ASPECTS OF PHYSICAL RECONDITIONING *

BY MARCUS J. STEWART, M.D., MEMPHIS, TENNESSEE

Conservation of manpower and the gainful existence of the individual following orthopaedic injuries and disease are attained not so much by the restoration of function, as by continually preserving function. Thus, in the initial treatment of fractures, reduction of the bone fragments should not be paramount, but rather the decision as to the most rapid method of restoring the whole individual to a functioning, economically solvent capacity. Surgical repair and treatment should be based on a program which will adequately immobilize the injured part, and at the same time maintain good tissue turgor and a properly functioning vascular tree, and allow early active exercise. In operative cases, it is as much the surgeon's responsibility to impress upon the patient the importance of postoperative care and proper muscle re-education as it is to employ good surgical technique. Each patient who faces more than a few days of convalescence should be given a detailed schedule of active rehabilitation,—especially a program of remedial exercises.

MILITARY REHABILITATION

The need for conservation of manpower in the British Army during World War I gave birth to the first large-scale systematic program of rehabilitation, under the guidance of a physical-training instructor. This plan thrived under the direction of Sir Robert Jones until the cessation of hostilities; it was then abandoned for twenty years. However, at the beginning of World War II, the system was quickly revived and inaugurated in the British Army under the guidance of the late General Rowley Bristow, and in the Royal Air Force by Sir Reginald Watson-Jones and Air Commodore Osmond-Clarke. The manpower salvaged by these rehabilitation centers and convalescent depots was, no doubt, one of the big factors which enabled the British to stand against seemingly insurmountable odds, and to stem the initial tide of the War.

A physical-training corps was established for the British Army at Aldershot, England, in 1680, and has since then functioned continuously. From this corps, physical-training instructors were assigned to the various hospital units of the Army and Royal Air Force, and, under close supervision and direction by the medical staff, they carried out their superb work.

The British Convalescent Depot is the stepping stone from hospital back to duty, and is the antecedent of what has been established in the United States Army Medical Corps as a Convalescent Center. The British Rehabilitation Center was formed for the conditioning of under-par inductees,—the men who, in the United States, would be classed as 4-F or placed on limited duty. For example, one of the British Centers, early in 1942, had received and processed about 5,000 of these inductees. The system of classification upon induction was to place a man in one of seven categories of physical fitness. Of these 5,000 men undergoing a planned program of physical conditioning, postural exercises, and training, the British were able to raise the category of physical fitness in 85 per cent., and of these, 77 per cent. were placed in A-1 classification.

In the United States Army in the European Theater of Operations, the dire need for a stepping stone from hospital to duty was evident. The initial 150-bed unit, which was established late in 1942, had expanded by May 1945 to include a program of 13,000 beds for convalescent reconditioning. This program alone returned over 60,000 men to full duty. During the last year of military operations in the European Theater, 15 to 20 per cent. of the total bed capacity was devoted to advanced reconditioning. Under this program, about

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 27, 1948.

90 per cent of the patients were returned to duty; of the 90 per cent, 83.6 per cent were battle casualties.

For example, in a series of men with back injuries, 415 patients were treated and studied. The injuries included 121 fractures of the spine, ranging in severity from forty-one patients with fractures of the transverse processes to twenty-seven with compression fractures of the lumbar bodies. These 121 patients spent an average of 117.3 days in the hospital. In the total series are included such cases as arthritis of the sacro-iliac joints, spondylolisthesis, incomplete sacralization of the last lumbar segment, myofascitis, and others. All of these patients were placed on a program of specific remedial back exercises, carried out by physical-training instructors under the direction of orthopaedic surgeons. The 415 patients spent an average of 101 days from the date of injury until return to duty. Of the total group, 92.3 per cent returned to duty in the European Theater of Operations; of these, 57.8 per cent returned to full military duty, and 7.7 per cent were transferred to other hospitals or returned to the Zone of the Interior.

Of the patients with chest injury, 418 were given a program of special rehabilitation and study. This group included sixty-nine cases of compound gunshot wounds penetrating the pleural cavity and lungs, 110 cases of hemothorax resulting from severe contusion and other injuries, twenty-three cases of pneumothorax, and various other types of chest injury. All of these patients spent an average of 112 days in the hospital under active treatment and a planned program of rehabilitation. Of the group, 86.6 per cent returned to duty in the European Theater of Operations, 4.5 per cent were returned to the Zone of the Interior, and 8.9 per cent were referred for more definite thoracic surgery.

Three hundred and nine patients with fracture of the carpal navicular were treated by plaster immobilization alone and returned to duty. The hand and wrist were held in mid-ulnar and radial deviation, and dorsiflexion of about 15 degrees, with the thumb and fingers in the grasping position. This position of the wrist was maintained by plaster, which extended from one inch distal to the elbow to the proximal palmar crease, and as far as the base of the thumb nail. These men were given a specific routine of remedial exercises for the affected hand, as well as general physical exercises.

After continual immobilization of two to fourteen months (an average of 4.2 months, depending to a great extent upon the location of the fracture), the restoration of function required an average of only three and one-half weeks before full, normal motion and strength were present in the hand and wrist.

These results in army rehabilitation were not obtained because of the virtue of any given series or specific type of exercises, but because exercises were enthusiastically taught and religiously executed in a sedulous and progressive manner.

INDUSTRIAL REHABILITATION

A great deal has been accomplished by reconditioning in the Armed Forces and in the Veterans Administration. Now, industry is rapidly developing programs of a similar nature. In Britain, industrial cooperatives, unions, and insurance companies are reclaiming untold manpower. In some American cities, insurance companies and industrial organizations are perfecting excellent programs. Many leading medical colleges and universities have well-advanced courses in programs of reconditioning. All industries and insurance companies are becoming aware of the value of reconditioning programs which include part-time employment. Partial pay for work and accomplishment helps to elevate the individual financially and mentally from the degrading compensation dole.

REHABILITATION IN PRIVATE PRACTICE

The private patients of today, compared with those from the military service or industry, are, in many instances, suffering from the lack of proper and thorough reconditioning. Many doctors feel that they must have an elaborate therapeutic gymna ore

they can offer their patients good reconditioning This is a completely erroneous idea As Watson-Jones points out, rehabilitation can be efficiently practised in a barn with no apparatus or gadgets

It has been our experience that it is best to develop, first, improvement in tone, coordination, and control by muscle tensing Then, non-weight-bearing, weight-resisting exercises should be started, using one, two, five, and ten pounds of resistance in a progressive manner until strength, endurance, and agility return If more power is desired, heavier weight resistance is indicated, as advocated by DeLorme In most patients, the range of motion will return in direct proportion to the improvement of the musculature controlling that joint

At the Campbell Clinic, remarkable improvement has been noted in many patients with various injuries, after a rather strict regimen of active muscle-building exercises had been instituted Improvement has been most outstanding in patients with back injuries, both chronic and recent, the results in cases of knee injury have also been of striking interest Three representative case reports are cited

CASE 1 Mrs E G, fifty-three years old, fell fifteen feet when a stairway banister gave way and she plunged to the floor She sustained a compression fracture of the ninth thoracic and second lumbar vertebrae, there were no neurological changes Under general anaesthesia, the fracture fragments were hyperextended, reduced, and maintained in a plaster body jacket After three days, she was placed on a program of exercises for the lower extremities and arms On the tenth day, she commenced back exercises in the plaster jacket At the end of three weeks, she could, by hyperextension, lift her head, shoulders, and the upper part of the cast off the bed forty-five times at one exercise period At the end of two and one-half months, the plaster was removed and the musculature of the back was found to be in excellent condition With the temporary aid of a brace, she returned to her job and has worked without interruption or complaint

CASE 2 Mrs E R, aged thirty-eight, related a history of pain in her back for ten years Since onset, there had been periods of remission and exacerbation, but she had never been entirely free from pain and disability Symptoms were located in the lumbar region, but there was no sciatic radiation Examination revealed an increased prominence of the spinous processes of the lower thoracic and upper lumbar vertebrae, with accentuation of the lumbar curve and a general increase in the thoracic kyphosis There was very little muscle spasm until motion was attempted, movement produced immediate fixation in flexion and extension, but lateral bending was possible to 50 per cent of normal Pressure on the lumbosacral joint was painful All leg signs were essentially normal, patellar and Achilles reflexes were normal Roentgenograms revealed an increase in the lumbar and thoracic curves, with osteo-arthritic changes, Schmorl's nodules, and evidence of old juvenile osteochondritis

The patient was given instructions in conservative care of her back, and was fitted with a low-back steel brace She did not wear her brace or follow instructions, but returned in one month with symptoms more severe than before She was admitted to the Hospital and was placed on a firm bed, adhesive traction was applied to both lower extremities, and heat treatments with gentle relaxing massage were given to the lower back After four days, back exercises were started She was discharged nine days later with explicit instructions concerning her exercise program After six weeks, she was free from pain and resumed normal activity

The patient was last seen ten months later and the following note was recorded "Patient states that she is remarkably improved and has had no pain in her back since beginning the series of exercises There is no muscle spasm, pain, or tenderness at this time Range of motion is essentially normal in all directions All special leg signs and tests are normal She was instructed at this time in more vigorous exercises, and advised to continue with the entire series"

CASE 3 F O, a male, aged fifty, gave the following history In December 1946, he fell and struck his knee on a concrete step Pain was not severe at the time of injury, and he required only palliative treatment Examinations for bone, cartilage, or ligament injury were all negative However, effusion, mild pain, and periarticular reaction developed over a period of weeks, and the knee became weak and unstable He had been seen in several nationally known clinics, and had been told that he should have an exploratory arthrotomy of the knee, but he had refused The condition of the knee grew worse, he became incapacitated and could not continue his work even with the aid of a brace

He was first seen by us in September 1947, examination revealed moderate effusion of the joint, no tenderness or ligamentous instability, but marked general laxity The musculature of the thigh was very weak, and marked atrophy was present He was unable to extend the knee more than three times against gravity Roentgenograms of the knee were negative except for early, mild, hypertrophic arthritic changes

A diagnosis was made of chronic traumatic synovitis with early arthritis. The patient was placed on weight-resisting exercises for the quadriceps and hamstrings. At the end of one week, tone in the muscles showed excellent improvement. In six weeks, the knee had become asymptomatic. A good musculature of the entire extremity had developed, there was no effusion, the patient could lift ten pounds of weight seventy-five times with the quadriceps, and could climb steps with ease. At this time, he returned to full employment.

Jostes has recently pointed out the importance of establishing and maintaining good body mechanics with correct posture, not for a given exercise period, but for twenty-four hours a day. He stated that good posture is found in "those emanating good health, confidence, courage, and personal cleanliness. Good posture is rarely associated with cringing, withdrawn characters, with slow-moving, weak, timid and dull individuals." He also stated: "Correct posture is, therefore, a dynamic concept involving proper use of all muscles and indirectly proper position of internal viscerae."

The two most essential steps in rehabilitation are, first, the proper instituting of early active exercises, and, second, a conscientious and enthusiastic effort on the part of the doctor to impress the patient with the importance and necessity of carrying out such a program. Unless the proper mental attitude and desire for recovery are well established in the patient, reconditioning plans will be for naught. Where possible, exercises for the involved part and deep breathing should be taught prior to surgery. After surgery or injury, exercises should be commenced as soon as the patient recovers from the anaesthesia, provided there are no symptoms of shock, cardiac failure, or other acute complications. Immediately after arthrotomy of the knee or nailing of a fracture of the neck of the femur, for example, exercises of the arms and unaffected lower extremity, with deep breathing, should be started. Muscle-tensing exercises should be started on the affected extremity on the first postoperative day. The patient may be allowed to sit up at this time, but ambulation is not necessary or indicated.

Recumbency and lack of active exercise are conducive to a multitude of ills,—poor circulation, embolism, pulmonary and cardiac congestion, osteoporosis, and poor callus. The metabolites of combustion in the tissues of the body, especially in the muscles, undoubtedly play a more important part in the proper healing and recovery of tissue than has ever been explained. Dock states: "Thrombosis is the most frequently fatal sequal of complete bed rest, and the common cause of serious pulmonary complications. *Hypostatic* bronchopneumonia is second in frequency, and is a more complex problem in which recumbency plays a contributing role of great importance." It is also known that nitrogen balance can seldom be established, even with a high-protein diet, in the face of inactivity and recumbency. Zava reported 6,000 patients operated upon, who were allowed out of bed on the first postoperative day, without a single case of embolism. Leithauser is given much credit for furthering early ambulation. In 1943, he reported 900 cases in which the patients were allowed out of bed in an average of 1.3 days, and out of the hospital in four days. There were no cases of pulmonary or other emboli. He stated that a common explanation for the presence of complications is "He got up too soon, but in reality, he got up too late." A large proportion of the fatal cases of embolism occur about the thirteenth day, or soon after the patient rises from a prolonged stay in the recumbent position.

Kummell advocated getting patients out of bed on the first postoperative day, following celiotomy. Pool stated in 1913 that he had had his own appendix removed and had commenced exercise on the third postoperative day; he had begun early ambulation with excellent results. He stated: "All movements of the limbs should be performed with voluntary muscular resistance." Pool continued, for the rest of his life, to be a strong advocate of early active exercise.

In 1930, Mermingas reported allowing his patients to walk from the operating room after undergoing appendectomies under local anaesthesia. Blain stated in 1946: "At our Clinic in the past three years, no patient getting out of bed within one or two days following operation has succumbed to pulmonary embolism, evisceration or other serious compli-

cation We have found that the distressing sequelae following operation, such as gas pains, constipation, weakness and urinary retention, have been eliminated in these patients

Opiates, sedatives, laxatives, stomach intubations and bladder catheterizations have all but disappeared from our post-operative order sheets for the majority of surgical patients

Ghormley pointed out that, although the pathological physiology of atrophy is not understood, it occurs from prolonged rest, and there is not only bone involvement, but involvement of all the soft tissues as well Normally, tendon sheaths and fasciae are smooth, glistening, and present a gliding surface, but in areas which have been immobilized for a period of time, the operating surgeon finds that the muscle surfaces are dull and anaemic, and that the development of adhesions is noticeable

Some of Dr Chandler's patients, who had had fusions of the lumbosacral joint, were recently seen by the author, they were sitting up in bed on the third postoperative day and were out of bed on the fifth day, leaving the hospital on the ninth or tenth day

Entirely too much time and effort have been spent in trying to convey the importance of a specific type or series of exercises The paramount objective should be to teach the patient the importance of systematic and regular exercises The initial step is the responsibility of the surgeon for the orientation of the patient, not only with the procedure, but also with the objective and goal

The ideal stepping stones to physical reconditioning of the patient are

1 An enthusiastic desire on the part of the patient and the doctor to attain and maintain the best possible function of the affected part and of the whole body,

2 The acceptance of a program of early, active non-weight-bearing and weight-resisting exercises, religiously executed,

3 Intelligent and systematic deep breathing, with conscientious maintenance of good posture,

4 The application of heat, massage, and special apparatus in selected cases

The doctor and the physical instructor must gain the patient's complete confidence and cooperation, the keynotes should be patience, sincerity, enthusiasm, and optimism The patient should be taught three important phases of muscle rehabilitation (1) contracting, (2) sustained contracture, and (3) complete relaxation The objective should be what is commonly referred to as *dynamic* physical reconditioning, or dealing with the specific therapeutic need of the individual, in contrast to physical reconditioning, which refers to general calisthenics

Strickland and Morgan quoted McCloy as stating, in an address on reconditioning delivered in 1944 "It has been found by experimentation in the physiological laboratory that an individual capable of enduring 18,000 kilogram-meters of work in a given time without rest, after two weeks' inactivity, in which time he is walking around but doing no other exercise, will retrogress until he has the ability to do only 8,000 kilogram-meters of work in that time"

There is no longer any question as to the importance or practical value of early active exercises, early ambulation, and weight-resisting exercises There is, however, a great divergence of opinion as to what type of activity is best and how it can be executed most effectively The need for an investigation of these questions is evident, in order that a yardstick or practical guide to reconditioning and early ambulation for orthopaedic injuries and diseases may be formulated

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DISCUSSION

Transfacet Bone Block For Lumbosacral Fusion

(*Continued from page 398*)

the fifth lumbar interval alone was bridged The percentage rose roughly to 17 when the fourth and fifth lumbar intervals were crossed Later cases in the series showed a lowering of this percentage to about 12 when the last two lumbar intervals were spanned The development of surgical technique has made a considerable difference in the percentage of successes, but mainly through the use of more finely divided graft material, material of more cancellous nature, and through the use of procedures which better stabilize the region

Among the 650 patients operated upon, approximately 1,300 spinal intervals were crossed with an incidence of pseudarthrosis of 12 per cent Since 1940, all results have been checked by superimposable roentgenograms and, although our technique has improved and more solid ankyloses have been obtained, the reportable pseudarthrosis rate has risen This is directly attributable to the better knowledge gained by the use of such roentgenograms, in the future, no results should be reported which are not based upon them Curettage of the facet area, followed by graft implantation, was not carried out in our series Reports on a similar series by Dr Alan DeForest Smith, in which the facet area was curetted and grafted, showed essentially the same percentage of pseudarthrosis Hence we prefer to leave the facets intact, to provide a normal stabilizing mechanism in case pseudarthrosis develops

It would have been somewhat difficult to use Dr McBride's technique in many of the spines we have seen Distraction he undoubtedly can obtain, but permanent stability of the grafts (beyond two or three weeks) might not be present routinely I believe that lately he has been using considerable supporting graft material, after placing his blocks in the facet region to produce distraction His ideas are logical and the results may be good

Such future advance as may occur in the art of spine fusion at the lumbosacral angle will probably not be the result of surgical techniques Further development of knowledge of the factors favoring bone growth and repair, both local and general, will undoubtedly help to reduce the percentage of pseudarthrosis

PSEUDARTHROSIS FOLLOWING SPINE FUSION *

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In 1911, Hibbs [33] and Albee [2] published descriptions of their respective operations for fusion of the spine. Since then, improvements and modifications of the original techniques and additional types of operations [5, 9, 10, 11, 19, 24, 25, 26, 29, 32, 46, 47, 49, 52, 56, 60] have been presented, as well as the application of these new surgical procedures in the treatment of a wide variety of diseases and deformities of the spine [20, 34, 35, 39]. The choice of the procedure for spine fusion in the treatment of these various clinical conditions has occasioned much debate since the first descriptions were published. The value of spine fusion in the treatment of tuberculosis of the spine [1, 8, 13, 16, 17, 18, 21, 30, 31, 41, 44, 48, 50, 57], of scoliosis [14, 38, 45, 54], and of instability in the lumbosacral spine [15, 22, 27, 39, 42, 51, 53], especially following disc removal [6, 7, 23, 28, 55], has been questioned. From its widespread use in orthopaedic practice today [3, 4, 16, 17, 23, 27, 51, 55, 58], it is evident that some success has followed this operation as applied in the past.

It is not the purpose of this paper to enter into a discussion of the indications for and the value of spine fusion. The authors are concerned with the basic question involved: Does this procedure result in fusion of the spine? By fusion, the authors mean the fixation of the spine by a continuous column of bone which allows no motion in any plane of the body, throughout the vertebral segments involved. It has never been completely ascertained [9, 12, 13, 14, 17, 57] how often spine fusion successfully occurs following this operative procedure, and to answer the question, an end-result study of the spine-fusion operation has been carried out.

MATERIAL FOR STUDY

All cases of spine fusion performed at the New York Orthopaedic Dispensary and Hospital from 1936 through 1945 have been reviewed. During this period, spine fusion was performed on 1250 patients. Of this number, 154 patients were not followed for one year after the operation and have been excluded from the study. Of the 1096 patients who have been followed, the results of operation are known; by this we mean that each patient has had repeated clinical examination and roentgenographic study for a year or more after operation. Multiple-stage procedures were performed in many cases. In the cases followed, a total of 1504 spine-fusion procedures have been carried out.

The Hibbs technique of spine fusion has been used in all of the cases [33, 35, 36, 37, 40]. The results shown here represent the efforts of the most experienced staff members, as well as those of surgeons performing their first spine fusion, under supervision. Although the Hospital staff has employed minor variations in technique, the technique of operation now being performed at the Hospital includes certain definite standardized steps [40]. Post-operative care, including immobilization, has also been generally standardized. An attempt to secure internal fixation has been considered a sufficient departure from the usual technique to warrant separate analysis. There were no operative deaths during the period of this study. The number of cases represented in each group are shown in Table I.

DIAGNOSIS OF PSEUDARTHROSIS

The diagnosis of pseudarthrosis was made after consideration of the clinical picture and

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 27, 1949.

roentgenographic findings Localized pain and tenderness, and the progression of deformity or disease, when present, aided in the establishment of the diagnosis Study of lateral roentgenograms of the fusion area, with the patient first in the flexed and then in the extended position, has been especially useful In certain cases the diagnosis of pseudarthrosis could not be made until the fusion area had been surgically explored Exploration was always advised when any doubt existed as to the state of fusion Relatively few of the patients in whom pseudarthrosis was suspected were unwilling to submit to exploration when it was suggested The thoroughness of the search for pseudarthrosis in these patients is shown by the fact that, in twenty-three patients who underwent exploration, a solid fusion was found For this reason the authors feel that there were very few patients in the entire group of 1096 cases in whom the status of the fusion was questionable

INCIDENCE OF PSEUDARTHROSIS

Scoliosis (Table I)

During the period of this study, 376 patients with scoliosis underwent spine fusion and have been followed for at least one year after removal of the final jacket A total of 744 primary operative procedures were carried out

Of this group of patients, the diagnosis of pseudarthrosis at one, or more than one, level was made in fifty-nine Thus, fusion failed in 15 6 per cent of all the patients with scoliosis who underwent the operation, or in 7 9 per cent of all the operations performed In fifty-one patients, the diagnosis was confirmed at exploration In the remaining eight patients, the diagnosis was made only by clinical and roentgenographic study In this group, permission for exploration was denied, but the evidence which was obtained indicated the presence or the possibility of pseudarthrosis, and these patients have been included in the group to illustrate failure of fusion

Fifty-one patients underwent repair of the fusion defect Exploration for pseudarthrosis was performed in fourteen more patients, and solid fusion was found The clinical features of pain and localized tenderness, and roentgenographic evidence of fusion defect and loss of correction, warranted such exploration Thus, of the group of sixty-five patients who underwent exploration for pseudarthrosis, the preoperative diagnosis was confirmed in fifty-one, or 78 4 per cent of the cases

Lumbosacral Fusion

This group includes all cases of lumbosacral fusion from the fifth lumbar vertebra to the sacrum, and from the fourth lumbar vertebra to the sacrum Fusion for spondylolisthesis and fusion with the use of internal fixation are treated separately Exploration for herniated disc is now done with little or no sacrifice of lamina, thus, the technique of the Hibbs operation does not need to be altered greatly when combined with disc exploration The combined type of operation has been included in this group because it is felt that the operation, as it is now performed, would have little or no effect on the incidence of pseudarthrosis This was not true during the early days of the development of this operation, when a great part of the lamina was sacrificed The operation, as it is now performed, has been done since 1940, statistics applying to the four years in which the more extensive type of exploration was done have been included in this study

Four hundred and thirty patients with fusion from the fourth lumbar vertebra to the sacrum, or from the fifth lumbar vertebra to the sacrum, with or without exploration for a herniated disc, have been followed during this period, and the results of operation are known Of this number, the diagnosis of pseudarthrosis has been made in sixty patients, or 13 9 per cent of all the cases followed In fifty-one patients, the diagnosis was confirmed by exploration, and the defect was repaired

TABLE I

INCIDENCE OF PSEUDARTHROSIS AFTER SPINE FUSION

Condition	No. of Patients	No. of Operations	Failures		
			Patients		Operations
			(No.)	(Per cent)	(Per cent)
Scoliosis	376	744	59	15.6	7.9
Lumbosacral fusion					
Fifth lumbar to sacrum	261	261	20	7.6	
Fourth lumbar to sacrum	169	169	40	23.6	
Lumbosacral fusion (with internal fixation)					
Fifth lumbar to sacrum	41	41	5	12.1	
Fourth lumbar to sacrum	49	49	27	55.1	
Spondylolisthesis	65	65	9	13.8	
Tuberculosis	101	141	21	20.7	14.8
Miscellaneous	34	34	1		
Total	1096	1504	182	16.6	12.1

Nine patients in this group refused exploration for pseudarthrosis. Clinical and roentgenographic findings, suggestive of failure of fusion, warrant their inclusion in this group with pseudarthrosis.

Eight patients underwent exploration for pseudarthrosis, and solid fusion was found; thus, of the fifty-nine patients who underwent exploration, with the preoperative diagnosis of pseudarthrosis, confirmation of pseudarthrosis was found at operation in fifty-one, or 86.4 per cent.

Of the 261 patients who were included in the group with fusion from the fifth lumbar vertebra to the sacrum, with or without disc exploration, the diagnosis of pseudarthrosis has been made in twenty patients, or 7.6 per cent. of the cases followed. Of the 169 patients who underwent fusion from the fourth lumbar vertebra to the sacrum, pseudarthrosis developed in forty, or 23.6 per cent. of the cases followed. The figures shown here are evidence of the increased risk of pseudarthrosis, when the fusion is extended from the sacrum to the fourth lumbar vertebra, rather than to the fifth.

Of the forty cases of pseudarthrosis which occurred in the group with fusion from the fourth lumbar vertebra to the sacrum, thirty showed fusion defect at the level of the fourth to fifth lumbar vertebra, seven at the lumbosacral level, and, in three cases, pseudarthrosis developed at both levels.

Internal Fixation

In an attempt to allow early ambulation after spine fusion, the employment of some type of internal fixation has been added to the usual technique of spine fusion [43, 59]. At this Hospital, it has been attempted by performing the usual type of operation and, in addition, by driving a stainless-steel machine screw of proper length across each of the apophyseal joints involved in the fusion. The patient is allowed out of bed at the end of two or three weeks, and no attempt is made to employ external support.*

Forty-nine patients in whom this technique was employed have been followed, each with fusion from the fourth lumbar vertebra to the sacrum. Pseudarthrosis developed in twenty-seven patients, or 55.1 per cent. of the group. The diagnosis was confirmed by exploration in nineteen cases, and repair was attempted. Of forty-one patients in whom

* Recently, some type of external support, usually a plaster jacket, has been applied to these patients, several days after operation and has been maintained from six to twelve weeks. The patients have remained in bed during this period.

the fifth lumbar vertebra was fused to the sacrum and internal fixation was employed, failure of fusion developed in five, or 12.2 per cent. of the cases. In four of these, the pseudarthrosis has been confirmed by exploration.

Spondylolisthesis

This group has been considered separately because of the degree of instability of the involved vertebrae found in such cases. Sixty-five patients in whom fusion was attempted have been followed during this period. In seven patients, fusion was from the third lumbar vertebra to the sacrum. In the others, fusion was from the fourth lumbar vertebra to the sacrum. There was failure of fusion in nine patients, or 13.8 per cent. of the cases followed. Three patients showed failure of fusion both at the level of the fourth to fifth lumbar vertebrae and at the lumbosacral level. Four showed failure at only the level of the fourth to the fifth lumbar vertebrae, and two showed failure at only the lumbosacral level. In two patients in this group, exploration was carried out for suspected failure of fusion, and solid union was found.

Fusion for Tuberculosis

The postoperative care in these cases has varied according to the indications in the individual patient. Bed rest and some form of external support, either a spine brace or a plaster jacket incorporating both thighs, has been maintained until arrest of the disease was evident.

During the period of this study, 101 patients with spine fusion for tuberculosis were followed for at least one year after operation, and the results of the operation are known. A total of 141 primary operative procedures were performed in the cases followed. In twenty-one patients pseudarthrosis developed at one, or more than one, level. Thus, in 20.7 per cent. of all the patients followed, or 14.8 per cent. of all operative procedures, failure of fusion has resulted. The diagnosis has been confirmed by exploration in eighteen patients, and the defect has been repaired.

Four patients underwent exploration for what was thought to be a fusion failure, but solid union was found.

Miscellaneous Group

In this group are included cases of fusion for old fracture, localized osteo-arthritis at other than the lumbosacral level, and cases of wedging round-back. Thirty-four patients who underwent fusion were followed during this period. One patient showed failure of fusion at the level of the twelfth thoracic to the first lumbar vertebra; this has not been repaired.

EXTRA BONE

Frequently, because the usual technique did not supply enough bone to ensure fusion, the surgeon has used additional fresh autogenous bone. This has been obtained from the ilium or from the tibia.

Of the group of patients fused for scoliosis, extra bone was used in seventy-four; pseudarthrosis developed in thirteen of these patients, or 17.5 per cent. Thus, the incidence of occurrence of pseudarthrosis is slightly greater in this group than in the entire group fused for scoliosis. Extra bone was used in forty-two patients fused for spondylolisthesis. In six patients, or 14.2 per cent. of the group, pseudarthrosis developed. In twelve patients in whom fusion was from the fourth lumbar vertebra to the sacrum, and in five patients in whom fusion was from the fifth lumbar vertebra to the sacrum, additional bone from the ilium was added. Pseudarthrosis developed in two of the first group and in none of the latter group.

SUMMARY

A study of the results of all spine-fusion operations performed during the ten-year period from 1936 through 1945, at the New York Orthopaedic Dispensary and Hospital shows that, of the 1096 patients followed at least one year from the time of spine fusion the incidence of pseudarthrosis has been 16 6 per cent

The diagnosis of pseudarthrosis can be made, in most cases, after careful clinical and roentgenographic evaluation In a smaller group of cases, the diagnosis will not be definitely established until the area of fusion has been explored

The benefits of the operation of spine fusion for any disease or deformity of the spine cannot be determined except in patients in whom a successful fusion has been definitely obtained

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INTRA-UTERINE FRACTURES OF THE TIBIA AND FIBULA

Report of a Case with Correction by Osteotomy and Plating

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From Roper Hospital, Charleston, South Carolina

Intra-uterine fractures may occur in several ways The first suggestion is trauma during pregnancy with indirect injury to the foetus Amniotic snaring off is another possibility, and was definitely the cause in the cases of Granzow and Koch

Diseases of the foetus to be considered in intra-uterine fracture are (1) osteogenesis imperfecta, (2) chondrodystrophies, and (3) syphilis Roentgenograms showing repair of a fracture in normal bone should rule these out There have been many reports of pathological intra-uterine fractures, for example, Snure reported over two hundred in cases of osteopsathyrosis A roentgenogram taken the first day or two after birth, showing either healing of normal bone or evidence of some bone lesion, would rule out an obstetrical fracture

The criteria for a true intra-uterine fracture of normal bone are roentgenograms showing absence of disease and normal repair of a fractured bone These films should be taken soon after birth, since callus forms so quickly in the newborn that roentgenograms taken even a week after delivery would not rule out a birth fracture

CASE REPORT

A white male baby (No 34142) was seen on May 20, 1942, one day after delivery The delivery had

Fig 1-A

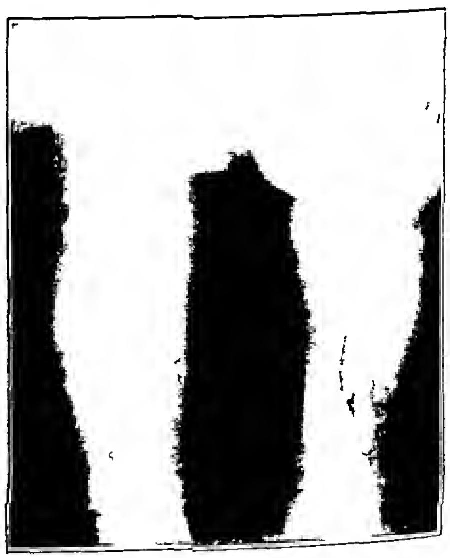

Fig 1-B

Roentgenograms taken on May 23, 1942, three days after birth The line of the intra uterine fracture at the junction of the lower and middle thirds of the left tibia is almost obliterated It can be seen in the lateral view, but not in the anteroposterior view The fracture line in the fibula has been completely obliterated Posterior bowing at the fracture site is 40 degrees in the lateral view, and medial bowing is 20 degrees in the anteroposterior view Bone texture is normal Length of the right tibia is 6 centimeters, that of the left tibia is 4 5 centimeters

FIG. 2-A

FIG. 2-B

Roentgenograms taken on August 19, 1942, two days after operation and three months after birth. The bowing at the site of intra-uterine fracture has been corrected completely, but a greenstick fracture is present at the upper screw, where posterior bowing is 15 degrees and medial bowing is 20 degrees. The lower end of the plate is 6 centimeters from the proximal tibial epiphyseal line and 0.3 centimeter from the distal tibial epiphyseal line.

FIG. 3-A

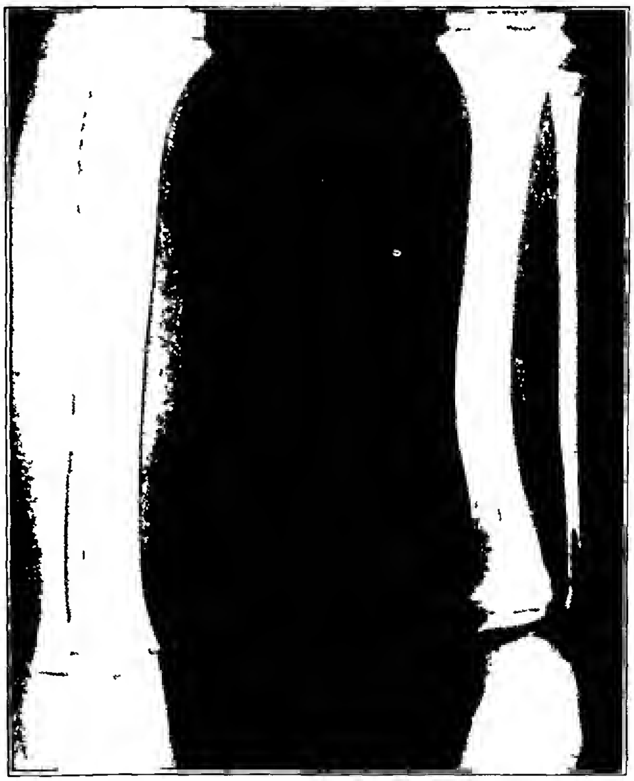

FIG. 3-B

Roentgenograms taken on August 21, 1947, five years after osteotomy. At the site of the intra-uterine fracture, the medial bowing has decreased to 12 degrees. Length of the right tibia is 18.6 centimeters, that of the left tibia is 17.8 centimeters.

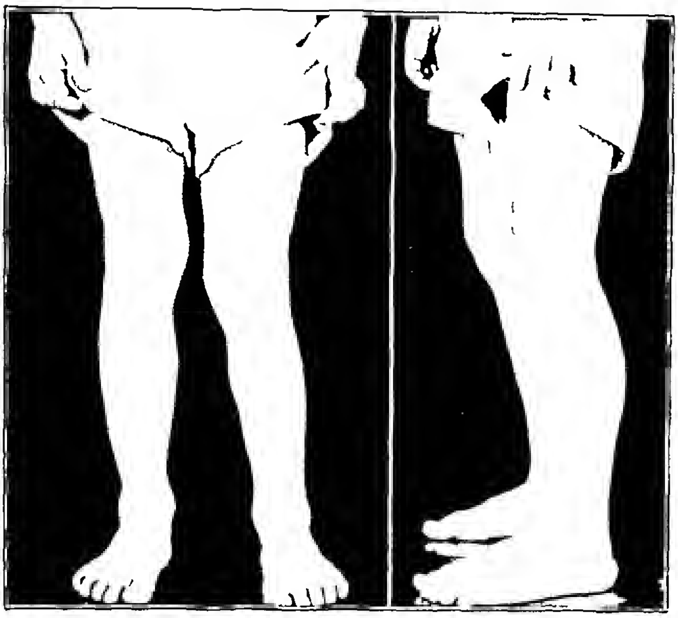

Fig 4-A *Fig 4-B*

Photographs taken in September 1947 The medial bowing of the left tibia is not noticeable clinically The left tibia is 0 8 centimeter shorter than the right, as measured in the anteroposterior roentgenograms

been an easy one Physical examination showed a normal baby except for the lower extremities Calcaneovalgus was present bilaterally The left leg was bowed 40 degrees clinically at the junction of the lower and middle thirds of the tibia and fibula This accentuated the calcaneovalgus to such a degree that the foot lay against the anterior surface of the leg The foot could be plantar-flexed from extreme calcaneovalgus to 80 degrees Roentgenograms taken three days after birth (Figs 1-A and 1-B) showed a faint fracture line and considerable thickening at the junction of the lower and middle thirds of the tibia Extreme posterior bowing was present in the lateral view, and slight medial bowing was present in the anteroposterior view Clinically, the posterior bowing of the lower portions of the tibia and fibula looked much worse than it did by roentgenogram The Wassermann reaction and other laboratory findings were negative

The diagnosis of intra-uterine fracture of the lower portions of the tibia and fibula was made, as from the normal bone texture seen in the roentgenograms, other diagnoses seemed remote Since the fracture line was almost obliterated, it was estimated that the fracture had taken place between two and three weeks before delivery There was no history of a fall or of other injury to the mother The films were reviewed by Albert Ferguson, M D , who confirmed the diagnosis of intra-uterine fracture

The bilateral calcaneovalgus was corrected easily by application of a series of four plaster casts

Roentgenograms, taken when the infant was six weeks of age, showed posterior bowing of 35 degrees at the junction of the lower and middle thirds of the tibia and fibula, and medial bowing of 25 degrees A corrective osteotomy was performed at twelve weeks of age at the apex of the posterior bowing, one inch above the distal tibial epiphyseal line When the posterior bowing had been corrected, there was a V-shaped gap with the open part of the V forward The posterior bowing was corrected entirely and the medial bowing was almost fully corrected The position was held by a small forearm plate and four screws of 18-8 SMo stainless steel

Postreduction roentgenograms (Figs 2-A and 2-B) showed both the posterior and medial bowing to be corrected, however, there was 20 degrees of medial bowing at the site of a greenstick fracture which had occurred at the upper screw Convalescence was uneventful

Roentgenograms taken when the child was five years of age (Figs 3-A and 3-B) showed that the posterior bowing had remained corrected, the medial bowing at the site of the intra-uterine fracture had decreased to 12 degrees At the age of five and one-half years, the patient's left leg looked normal (Figs 4-A and 4-B)

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MUSCLE TRANSPLANTATION FOR TRICEPS PALSY

The Technique of Utilizing the Latissimus Dorsi *

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Although the triceps is not a key muscle in the arm, the loss of its use is reflected in a varying degree of ataxia in the upper extremity. This is particularly noticeable in persons who have other muscle paralyses or weakness in the same extremity,—for example, those suffering from the after-effects of poliomyelitis, and others who have triceps weakness combined with various types of weakness affecting the finger flexors. The latter conditions are commonly seen in persons who have had a combination of injuries to the radial and ulnar nerves or to the radial and median nerves. A strongly functioning triceps is required for the effective use of crutches, and extension of the entire upper extremity is impaired by weakened or absent forearm extension due to triceps palsy. It is desirable to have numerous possibilities for surgical rehabilitation of the upper extremities.

Muscle transplants for strengthening forearm extension have not received sufficient attention, as many orthopaedic surgeons consider the disability due to isolated triceps palsy as minimal, because of the favorable effect of gravity in securing elbow extension in many positions of the upper extremity. Ober and Barr have proposed posterior transplantation of the muscle belly of the brachioradialis for triceps palsy. Unfortunately, many of the patients who desire the strengthening of extension at the elbow also have weakness or paralysis of the biceps and brachioradialis. On the other hand, in patients demonstrating the after-effects of poliomyelitis, the latissimus dorsi may be intact. This muscle is ideal for substitution of the triceps for the following reasons:

1. It often is of normal or nearly normal strength in persons who have weakness of the triceps and other arm and forearm muscles;
2. Its tendon and distal muscle fibers can be mobilized medially for a distance of six or more inches;
3. The nerve supply of the latissimus dorsi (the thoracodorsal nerve) is a free-lying trunk, from five to seven inches (12.5 to 17.5 centimeters) in length†, which is highly mobile and easily identified;
4. The blood supply of the latissimus dorsi enters from a wide zone in the proximal third of the muscle;
5. The operation of mobilizing the tendon of the latissimus dorsi and transferring it to the aponeurosis of the triceps is accomplished in a single, relatively restricted area in the posterior upper two thirds of the arm (Fig. 1).

OPERATIVE TECHNIQUE

The operation is carried out with the patient lying on his side in a slightly anterior oblique position, with the involved extremity uppermost. The skin incision (Fig. 1,*a*) begins one inch posterior and below the posterior inferior acromial tip, extending laterally for two inches and then downward over half the length of the upper portion of the arm at the posterior mid-line. The deltoid, latissimus dorsi, teres major, and the long head of the triceps are readily identified, since these are the muscles which give substance to the posterior axillary fold. The latissimus dorsi (and, if necessary, the teres major) is easily detached from its insertion into the medial bicipital ridge of the humerus; it is then

* This study was aided by a grant from the National Foundation for Infantile Paralysis, Inc.

† Measurements made by the author on thirty-three cadavera.

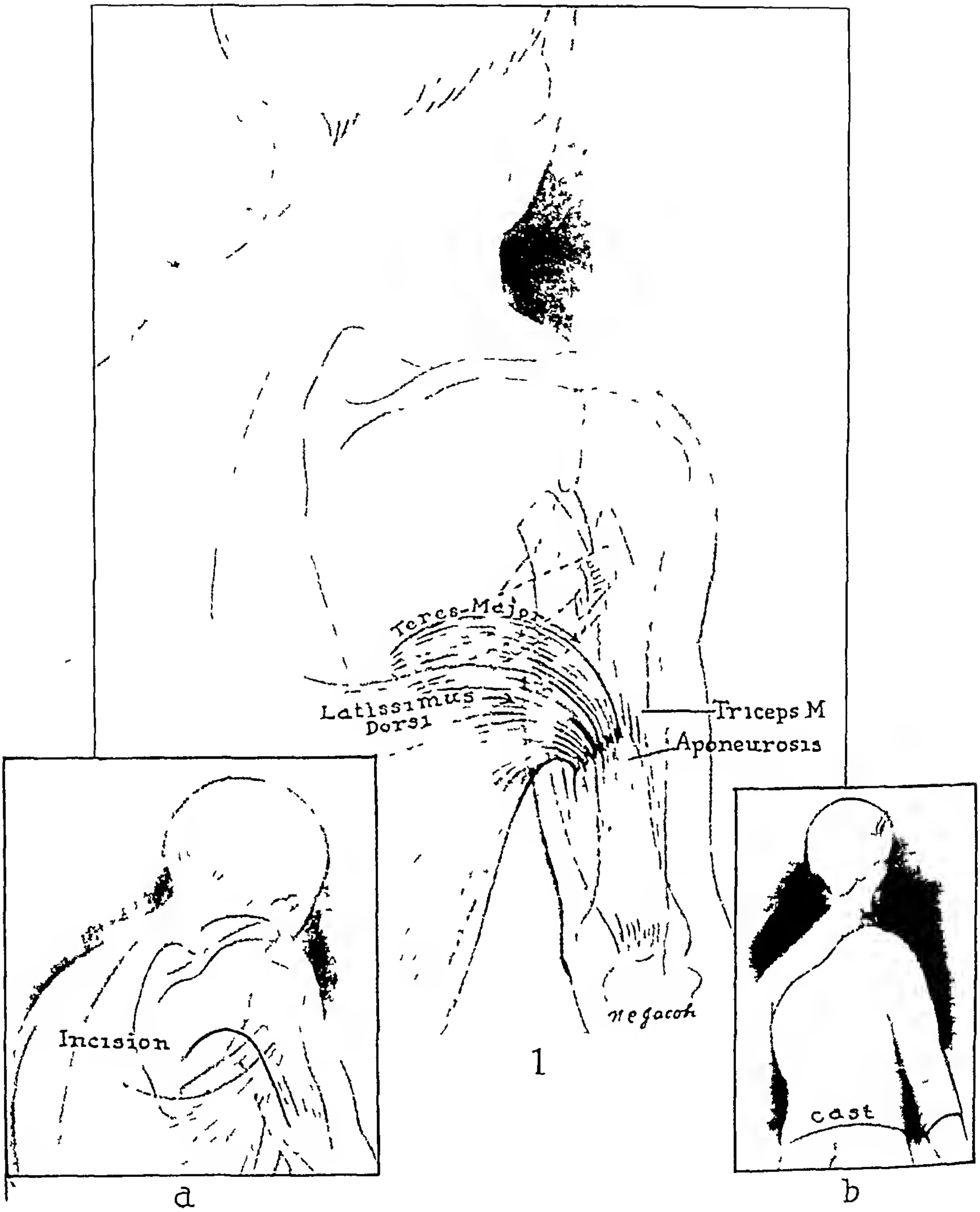

Fig 1

Diagrammatic representation of surgical technique of transferring the latissimus dorsi and teres major into the triceps aponeurosis for the purpose of restoring extension of the elbow in triceps palsy Inset *a*, the skin incision Inset *b*, position of immobilization in the cast

freed of loose connective tissue, and is directed downward in line with the long head of the triceps, and fixed to the triceps aponeurosis with interrupted non-absorbable stitches (Fig 1)

Caution should be observed when freeing the latissimus dorsi from its insertion and in the dissection immediately preceding and following this procedure The upper portion of the radial nerve lies just anterior to the tendons of the latissimus dorsi and the teres major The trunk of the ulnar nerve and the axillary artery and veins are in close proximity, slightly more anterior at this same level Attention should also be given to the structures which emerge from the quadrilateral space (posterior circumflex vessels, axillary

FIG 2-A FIG 2-B

Appearance of the patient prior to transplantation of the latissimus dorsi and teres major
Fig 2-A Showing inability to maintain extension of the left elbow
Fig 2-B Showing the only position in which boy could balance the forearm on the arm in semi-extension

nerve and its branches, including the lateral brachial cutaneous nerve) by avoiding this area This can easily be done by keeping the dissection deep and distal in relation to the posterior deltoid margin When the posterior deltoid is atrophic, these structures are more likely to be encountered

The report of an ideal end result from this operation is described below In this case both the latissimus dorsi and the teres major were utilized for the transplantation

D L M, aged ten, had an almost complete paralysis of the left triceps and lack of true opposition of the left thumb, twenty-two months after an acute attack of poliomyelitis The patient was unable even to initiate elbow extension in any position of the upper extremity except in the arm-at-side position (Fig 2-A) This distribution of paralysis had been stationary for the preceding sixteen months Other muscles of the left upper extremity, although slightly atrophic, were functioning normally On August 15, 1947, the latissimus dorsi and the teres major on the left were freed from their humeral insertions and mobilized proximally It was found that the arm-at-the-side position was optimal for the most distal anchorage of the tendons of the two muscles into the triceps aponeurosis (Fig 1) This same position was utilized for postoperative immobilization (Fig 1,*b*)

The cast was removed three and one-half weeks after the operation It was noted that some degree of extension of the forearm against gravity was possible on this same day Strength of extension quickly improved Five and one-half weeks after operation the range and strength of elbow extension, with the humerus abducted 90 degrees or more, were almost the same in the left arm, which had been operated upon, as in the normal right arm (Figs 3-A, 3-B, and 3-C) Overhead elevation at the left shoulder was 10 degrees less than that of the right shoulder at this time, but this small discrepancy disappeared Three months later, the only difference detected between the left arm and the normal right arm was the slightly lower position of the left posterior axillary fold, due to the direction taken by the bellies of the transplanted muscles Strength and

The pathologist's report (by Dr Otto Saphir) stated that the biopsy revealed a fibrosarcoma These sections were also seen by the late R H Jaffe, at Cook County Hospital, who concurred with Dr Saphir's diagnosis

Physical examination showed an ulcerated area, about two inches in diameter, from which protruded a fleshy mass, stasis pigmentation was seen about the ulcer The examination was otherwise not remarkable

Roentgenographic study, reported by the late Dr Hubeney, disclosed that the left lower extremity was the site of an old osteomyelitis of the tibia, with a secondary destructive lesion and an accompanying advanced degree of arteriosclerosis (Fig 1) Films of the chest showed no evidence of metastasis, but old adhesions of the diaphragm were present at the base of the right lung

On September 12, amputation was done through the lower third of the left femur, following the administration of 500 cubic centimeters of whole blood The patient made a satisfactory recovery

Examination of the pathological specimen revealed an oval defect, 4 by 6 centimeters in diameter, in the lower third of the tibia, anteriorly The lower margin was covered by soft, pinkish-tan, fleshy tissue The popliteal artery was thin-walled and the lumen was patent On sectioning in the region of the skin defect, a dense white tissue was found, which extended for thirty millimeters into the medullary substance The medulla of the bone, above and below the tumor mass, was very dense (Fig 2)

The defect in the bone was filled by tissue which varied in microscopic appearance On the surface was a thick layer of necrotic tissue, which was mixed with blood and disintegrating pus cells Beneath this was an abundance of loose fibrillar connective tissue with large fibrocytes, here and there infiltrated by small round cells This connective tissue merged with a very dense connective tissue which surrounded irregular spicules of bone (Fig 3) Attached to these spicules were rows of osteoblasts Scattered throughout, but especially in the deeper portions, focal areas of great cellularity were present In these areas the fibrocytes were very large, their nuclei were pleomorphic, and numerous mitotic figures could be seen (Fig 4) The atypical fibrocytes often attached themselves to thin-walled capillaries and were mixed with small round cells and plasma cells (Fig 5) At the edge of the sinus in the skin there was a marked proliferation of the surface epithelium, which often extended deep into the underlying connective tissue, forming anastomosing cords with small horn pearls The histological picture was that of a fibrosarcoma of a moderate degree of malignancy, associated with

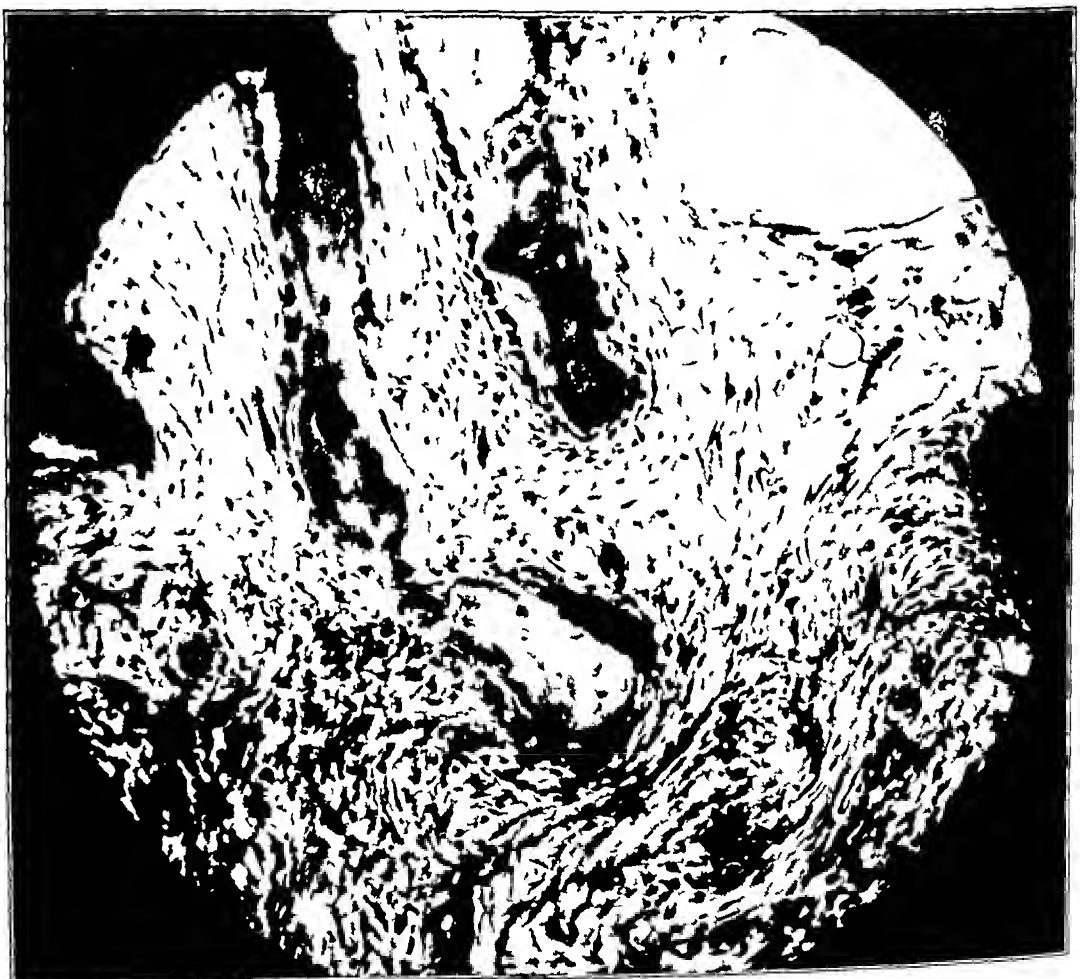

Fig 3

Photomicrograph (×500) of section taken from tibia, distal to the tumor, to show the non-specific chronic inflammatory changes

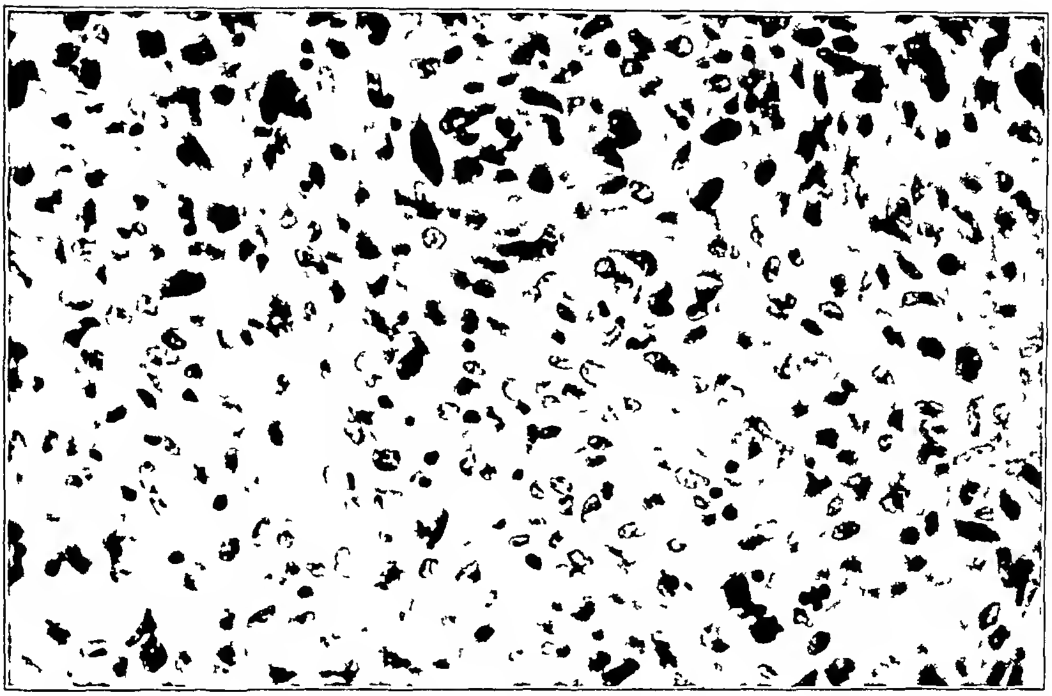

Fig 4
Photomicrograph (X415) shows the fibroblastic appearance of the tumor Section was taken from the deeper layer

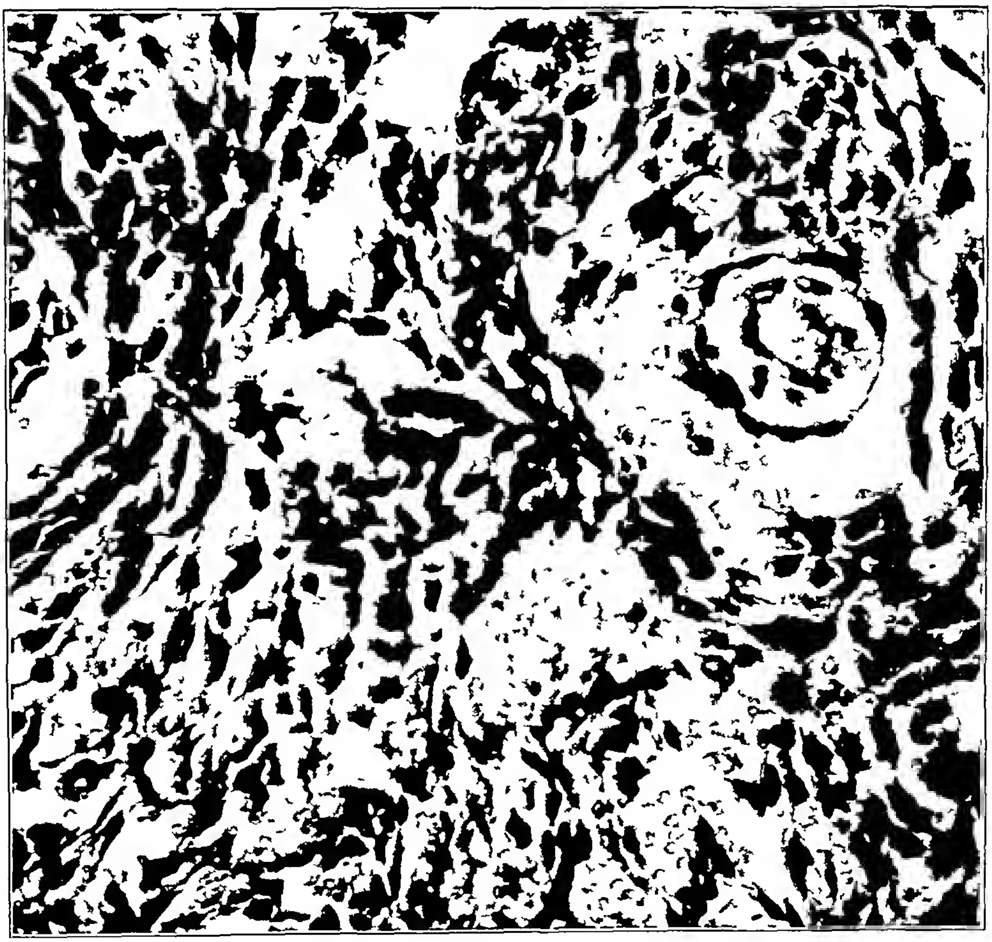

Fig 5
Photomicrograph (X500) shows the spindle-cell character of the tumor, in section taken from a more superficial layer

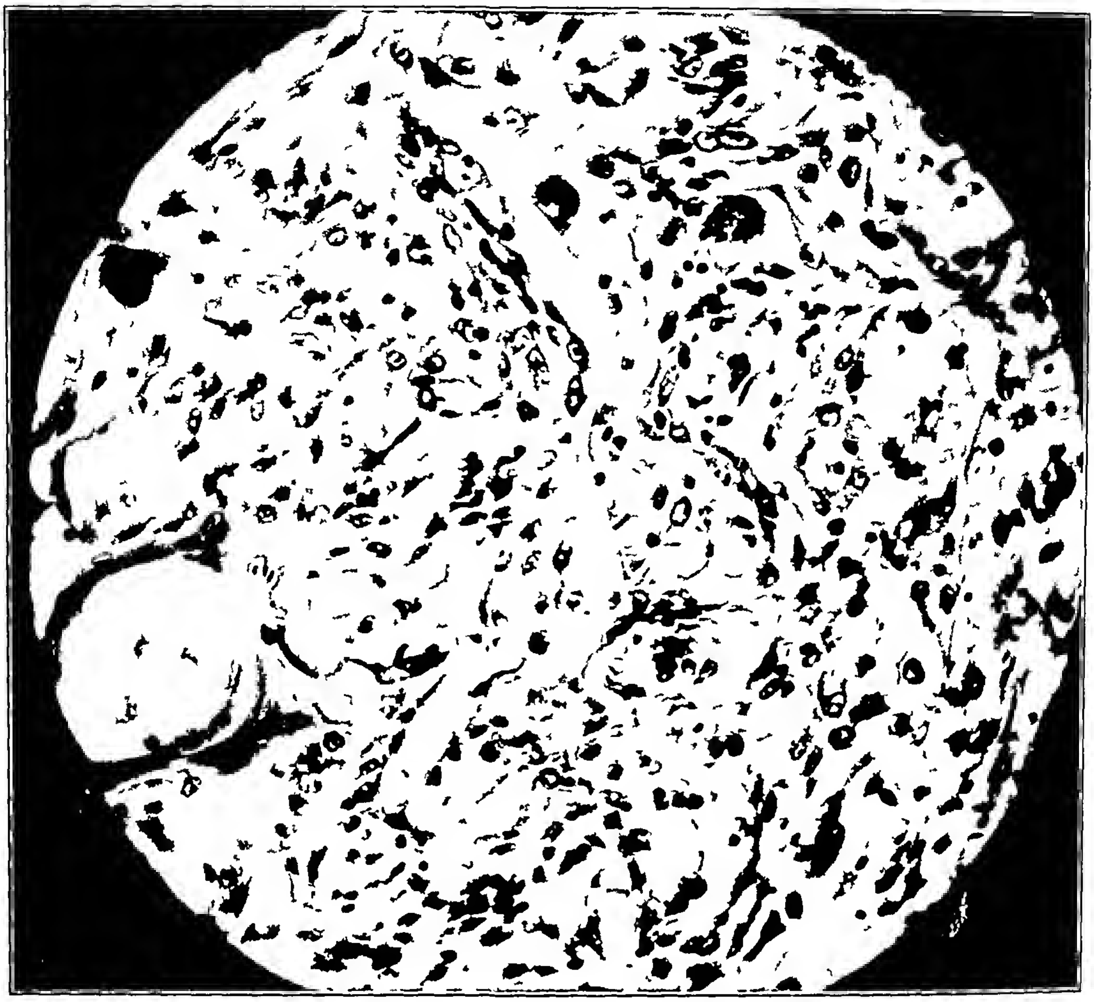

FIG 6

Photomicrograph (×500) of section taken near the surface Note single horn pearl, surrounded by granulation tissue with foreign-body giant cells

chronic osteomyelitis of the tibia The formation of horn pearls was probably a response of the inflammatory reaction and was not associated with an epidermoid carcinoma (Fig 6)

The diagnosis of fibrosarcoma, made by biopsy, was subsequently confirmed by studies of the neoplasm removed from the amputated extremity The patient was followed for three years, and no evidence of metastasis was found in that time

SUMMARY

Sarcoma following a chronic inflammatory process in such regions as the kidney, liver, or breast is well known, and there is no reason why a neoplasm, such as fibrosarcoma, may not develop in bone which is the site of osteomyelitis However, sarcoma in bone has rarely been preceded by osteomyelitis The case described supports the theory of chronic inflammation as a predisposing factor in the formation of malignant neoplasms

The tumor in this case probably had its origin in the fibrous bone marrow of the tibia

1 GESCHICKTER, C F Personal communication

CALCIFICATION OF THE BURSAE OF THE KNEE*

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A search of the literature has failed to disclose any report of calcification of the bursae of the knees. However, Brantigan and Voshell stated that calcification of the superior bursa beneath the tibial collateral ligament might "account for certain cases of Pellegrini-Stieda disease." Search of the records of the Mayo Clinic then yielded eight cases of calcification of the bursae of the knee.

The more important bursae about the knee, of which eighteen or more have been described [1,2,3], are (1) the prepatellar bursa, located anterior to the lower half of the patella, (2) the infrapatellar bursa, located between the tibia and the lower portion of the patellar ligament, (3) the superficial pretibial bursa, located over the insertion of the patellar ligament, (4) variable bursae[1] situated below and above the collateral ligaments, and (5) numerous and variable popliteal bursae. Chief of the popliteal bursae is the gastrocnemius semimembranosus bursa. The popliteal bursae often communicate with the synovial cavity of the knee.

The exact mechanism of the production of heterotopic calcification is not known. The statement of Watson Jones and Roberts in this connection is of interest. They said that in bone, normal circulation results in normal calcification, increased circulation in decal-

FIG. 1-A FIG. 1-B

Case 6. Calcification in the prepatellar bursa of a woman fifty years old, as seen in the anteroposterior and lateral views.

* Abridgment of a portion of thesis presented by Dr. Norley to the faculty of the Graduate School of the University of Minnesota, in partial fulfillment of the requirements for the degree of Master of Science in Orthopaedic Surgery.

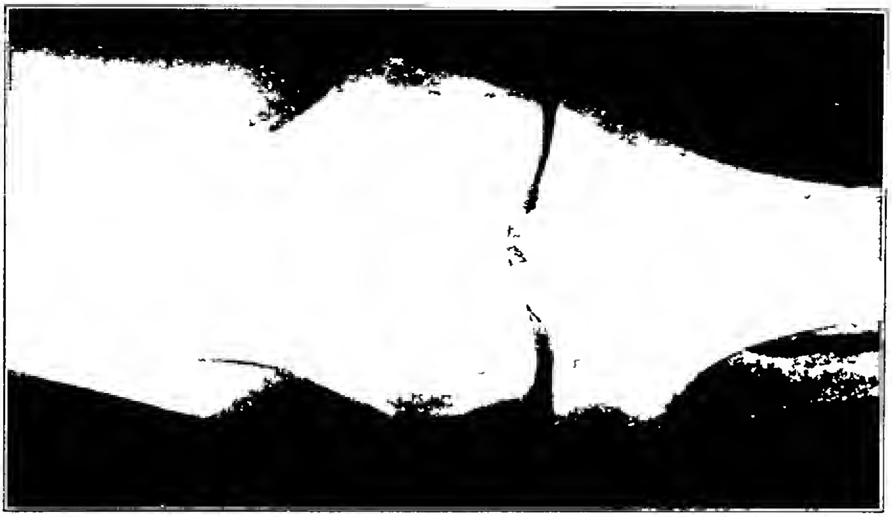

Fig. 2-C

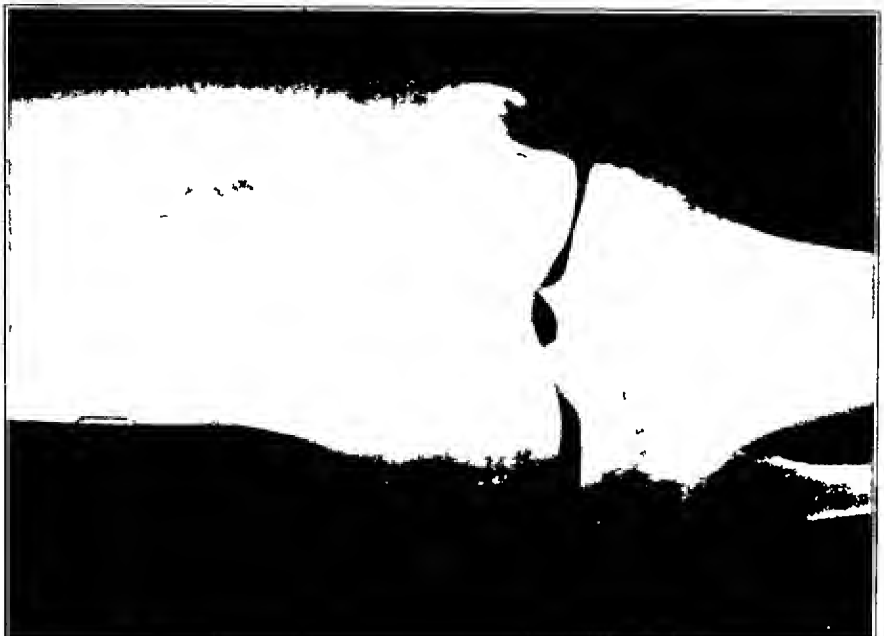

Fig. 2-B

Fig. 2-A

Case 8. Calcified bursa over medial condyle of the femur of a woman, fifty-eight years old.

Fig. 2-A: Before injection of procaine hydrochloride into the bursa. Fig. 2-B: Five weeks later, deposits of calcium are being absorbed. Fig. 2-C: Three and a half months after injection of procaine hydrochloride, calcium has disappeared completely.

cification, decreased circulation in increased calcification, and cutting off the blood supply in unchanged calcification. In any mesenchymatous tissue of low metabolism, decreased circulation results in pathological calcification, especially in the presence of fibrosis of trauma or infection. Fibroblasts plus an excess of calcium plus an adequate blood supply result in bone.

CLINICAL DATA

The eight patients complained of progressive pain on motion, of swelling, and of limited motion. Physical examination usually revealed a tender swelling over the involved bursa. Crepitus sometimes was present, in addition to limited motion. Calcification within the bursa was not usually suspected until its presence was revealed in the roentgenogram. One patient had recurrent painless swelling without any localizing signs, and the roentgenograms revealed calcification of the bursa over the medial condyle of the femur.

Of the eight patients studied, four gave a definite history of injury and most commonly of repeated traumata over a period of years. One patient, a man sixty years old, remembered no injury, but had a painless recurrent swelling of the knee. No injury was mentioned by the remaining three patients.

Locations of the calcified bursae were: prepatellar bursae in two cases (Figs. 1-A and 1-B), infrapatellar bursa in one, bursae over the medial femoral condyle in four, and bursa over the lateral epicondyle in one case.

TREATMENT AND RESULTS

As in the treatment of calcified bursae anywhere in the body, needling and the injection of procaine hydrochloride or surgical excision may be curative; the more conservative means should be used first if the symptoms are not too severe.

Needling and the injection of procaine hydrochloride were carried out in Case 8, in which the bursa was over the medial femoral condyle (Fig. 2-A); relief of symptoms and complete disappearance of the calcium were noted in three and a half months (Figs. 2-B and 2-C). This patient had associated diabetes and para-articular calcification of both hips. She had had seven diathermy and massage treatments in this same period.

Another patient (Case 1) had a calcified bursa excised from over the medial femoral condyle. One calcified prepatellar bursa was also removed surgically (Case 3). No follow-up data are available on these two patients. The roentgenograms in Case 3 were negative for calcification, but the gross specimen contained deposits of calcium. One other patient (Case 6) was advised to have a calcified prepatellar bursa removed surgically, but this was not done (Figs. 1-A and 1-B). One patient (Case 4) with a calcified bursa over the lateral femoral condyle had patellectomy for painful traumatic arthritis of the patella. One year later the patient reported a successful result from the patellectomy and no complaints referable to the knee. One other patient with similar calcification of a bursa over the medial femoral condyle was advised to have heat and massage to his knee. He had been kicked twice by a horse on the medial aspect of the knee and had had pain for five years. Calcification was not considered of significance in this case.

PATHOLOGICAL FEATURES

Microscopic examination of the two bursae removed surgically showed extensive deposits of amorphous calcium and inflammatory reaction within the bursal tissues.

COMMENT

Calcification may occur in any of the bursae about the knee and may cause disability and symptoms. Cures may be effected by local injection of procaine hydrochloride and needling or by surgical excision. This lesion is not common; it has been encountered only infrequently at the Mayo Clinic, and no report has appeared in the literature, as far as the authors could ascertain.

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AMPUTATION FOR DISCREPANCY OF LIMB LENGTH IN TUBERCULOSIS OF THE HIP

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Orthopaedic surgeons, in the not-too-distant past, have been accustomed to see, on their Services, patients with tuberculosis of the hip, lying in hip spicas for months or years, awaiting the "optimum" time for treatment

Gill, in 1944, presented his succinct observations and hypotheses concerning the ravages of this so-called conservative procedure,—namely, that the severe osteoporosis resulting from prolonged immobilization produces profound changes in the bone about the distal femoral and proximal tibial epiphyses, making it susceptible to minimal trauma and resulting in growth impairment, deformity, and ultimately in marked limb-length discrepancy.

Ross, in a recent paper, reiterated Gill's observations that growth disturbances will result from such "treatment", but added to the list, headed by tuberculosis of the hip, any disease which causes or necessitates prolonged disability He also claimed that growth retardation occurs before growth arrest, thus making the process reversible if the first stage, that of retarded growth, has not progressed to growth cessation This can be demonstrated when the disability ends relatively soon, bringing to a close the period of uselessness of the extremity, then bone atrophy will diminish, the epiphysis will assume a more normal appearance, and limb-length discrepancy will not increase His theory of the etiology of this condition differed from Gill's hypothesis

Both authors agreed, however, that, in addition to the prolonged disability which produces the osteoporosis, trauma to the epiphysis is necessary to retard or to stop growth Each hypothesized differently as to why the epiphyses are so susceptible and as to what constitutes the trauma Gill felt that the soft, atrophic, almost liquid, degenerated bone on each side of the epiphyses causes buckling of the curtain-like cartilage plate, due to bending of this pliable area as a result of changes in the intramedullary pressure This ruptures the epiphyseal plate or the small vessels going to it, thus damaging the growth center Ross propounded the theory that the cartilage partially degenerates as the result of atrophy of disuse and, therefore, retards growth, that it is unable later to withstand added stress, because of the faulty gait resulting from deformities, and that

this finally causes growth arrest, as a result of complete degeneration of a portion of the epiphyseal plate and the repair of the defect so formed by a bony bridge.

Gill's hypothesis could explain deformities and growth arrest in patients who have *not* caused weight trauma to the epiphyses, but the change might result from trauma, occurring inadvertently at the time of cast changes, surgery, or manipulations. Ross, however, stressed that growth retardation and arrest occur most frequently in the areas where stress and strain are concentrated, and pointed out that the elastic cartilage resists fracture, which would indicate that weight-bearing is an etiological factor. We believe that both theories are important in explaining growth changes in these extremities after prolonged disability.

However, from both authors' views and from common experience, we think one should promulgate certain axioms concerning the prophylaxis of this serious complication, especially in tuberculosis of the hip, for certainly everyone should be in agreement about this phase of the problem.

1. Long periods of immobilization prior to surgery should be avoided.

2. An adequate arthrodesis should be performed as early as possible,—that is, as soon as the patient's condition permits. The criteria for judging the optimum time for surgery in these tuberculous patients are as follows:
   - A. Weight stabilization or, preferably, weight gain;
   - B. Slowing of the pulse rate with stabilization;
   - C. Falling or stabilization of the temperature curve;
   - D. Leveling of the sedimentation rate.

This concept has been advocated by Chandler for many years, and in Pease's recent paper [4], in which he presented a five-year follow-up of twenty-eight cases of tuberculosis of the hip with early arthrodesis, by the use of the Chandler technique [1], there was not one case of serious or even consequential growth retardation or arrest [5]. In contrast, McCarroll and Heath presented cases with major deformities and resulting marked limb-length discrepancies in a similar group of patients who were treated with prolonged immobilization prior to arthrodesis.

3. Weight-bearing in the spica cast to reverse the osteoporotic process by physiological stress should be started as soon as possible after surgery, usually within six weeks, with careful supervision of the patient's activity to prevent trauma to the epiphysis.

4. Handling an osteoporotic limb during cast changes, surgery, et cetera, should be done with extreme care, especially if the extremity is tender to any degree.

We believe there is also unanimity of opinion as to treatment when partial or complete growth delay, or arrest, occurs. Such procedures as completion of the arrest of incompletely fused epiphyses, equalization of limb length by epiphyseal arrest in the uninvolved extremity, limb-shortening and limb-lengthening operations, osteotomies to correct the deformities of tibia recurvata or tibia vara, or combinations of one or more of these, are indicated.

It is not within the scope of this paper to discuss these methods. However, the problem arises of what should be done if the patient has marked shortening with such severe deformities that a weight-bearing extremity cannot be restored, as is frequently seen and was strikingly demonstrated in McCarroll and Heath's recent series. A case is presented which posed such a problem, the solution of which will demonstrate a method for adequate treatment.

A white boy was first admitted to the University of Illinois, Orthopaedic Department, on May 7, 1937, at the age of three years. He was subacutely ill and his right hip was fixed at about 90 degrees of flexion, slight abduction, and external rotation. There was swelling, muscle spasm, and pain in this hip on palpation and motion. The patient had a fever of 100.6 degrees. There was an inadequate history of increasingly progressive difficulty with the extremity for about four months. Prior to the child's admission, his father had died of pulmonary tuberculosis, his mother was seriously ill with the same disease and died a few months later.

Fig 1

Fig 2

Fig 3

Fig 1 Roentgenogram showing arrest of the tuberculous lesion of the right hip by fusion of the joint

Fig 2 Photograph of patient's lower extremities shows the marked shortening, atrophy, and deformity of the right lower extremity as compared to the left

Fig 3 Roentgenograms of the right leg revealing the marked bowing, asymmetry of the epiphyseal ends of the bones, thin tortuous fibula, and generalized bone atrophy

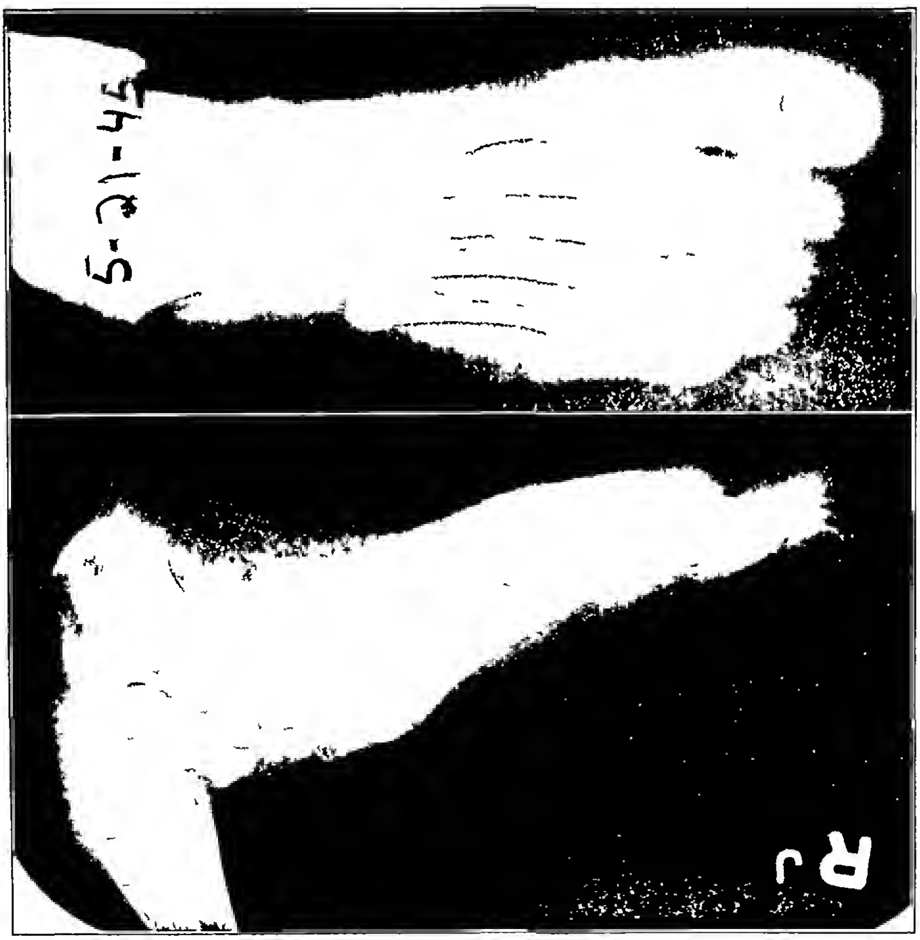

Fig 4

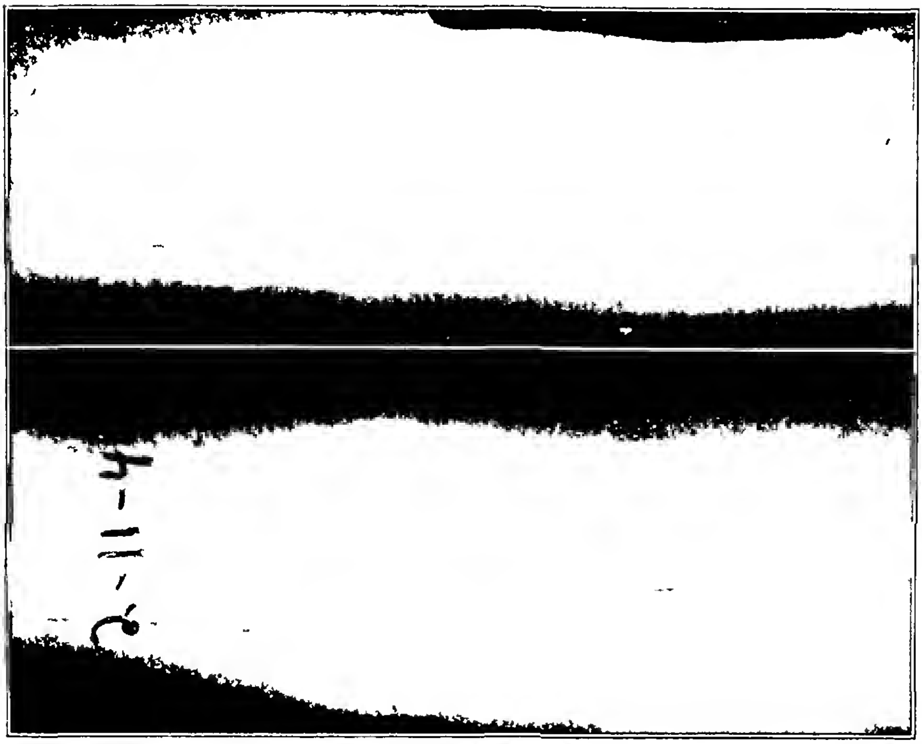

Fig 5

Fig 4 Roentgenograms of the right foot reveal the marked calcaneocavus deformity and severe osteoporosis

Fig 5 Roentgenograms of the knee, taken six months after fusion operation, show successful arthrodesis of the joint The obliquity of the joint line, due to irregular closure of the epiphyseal lines (which, although closed, are still apparent), demonstrates the typical deformities seen about the knee after long immobilization of the lower extremity (The site of amputation is in a portion of the leg distal to that shown in the roentgenograms)

The patient's right lower extremity was placed in balanced traction Aspiration of the hip-joint fluid was done about two weeks after admission Approximately 30 cubic centimeters of thick, green, purulent material was removed for bacteriological examination and guinea-pig inoculation The cultures were negative, but subsequent autopsies of guinea pigs corroborated the clinical impression of tuberculosis of the right hip

The patient's deformity and muscle spasm improved as a result of traction, and about seven weeks after admission, a double hip-spica cast was applied After seventeen months, during which several cast changes were made, the patient was discharged from the Hospital His sedimentation rate had decreased to 3 millimeters per hour (Wintrobe method) and he was gaining weight

The boy was followed in the Out-Patient Department for the next three years, having frequent cast changes, and on April 25, 1941, was readmitted to the Hospital for possible surgery Because of a rather severe febrile reaction, another double hip-spica cast was applied with "manipulation of the knee in an attempt to overcorrect the varus deformity by forcing it into slight valgus" The foot also was manipulated in an attempt to correct the calcaneovalgus (This would tend to corroborate Gill's view that weight-bearing is not necessary to cause epiphyseal damage This patient had not been bearing weight while in his cast)

About six weeks after his readmission (June 16) an arthrodesis was performed on the right hip, a graft from the right fibula was driven up through the trochanter and neck into the ilium, and a cast was reapplied The patient made an uneventful recovery and was discharged four months after operation (October 16) He was seen from time to time in the Out-Patient Department and his spica cast was changed periodically

On July 3, 1942 (thirteen months after operation), there was failure of the arthrodesis, both clinically and roentgenographically Another fusion of the hip was done on July 27, the regenerated right fibula was used as an extra-articular graft, wedged across the joint from trochanter to ilium The postoperative course was again uneventful and the patient was discharged, six weeks after operation, in a double hip-spica cast He was followed in the dispensary for the next year and, at the time his casts were changed, an increasing deformity of the tibia was noted with instability of the knee joint Up to this time fusion of the hip had not occurred, and a single hip spica was applied on March 8, 1944, so that the patient could bear weight On May 26, 1944, there was clinical and roentgenographic evidence of fusion (almost two years after his second operation), but a single hip spica was reapplied

Fig 6

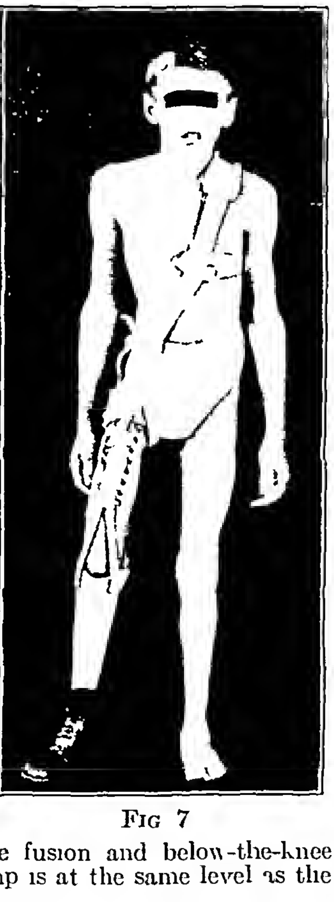

Fig 7

Fig 6 Photograph after knee fusion and below-the-knee amputation The end of the stump is at the same level as the opposite knee joint

Fig 7 Patient, at the time of discharge, wearing his prosthesis

The patient was readmitted on May 14, 1945, at the age of eleven, almost eight years after his initial admission At this time, his hip was fused (Fig 1), but the right lower extremity was deformed and atrophic with 13 75 centimeters of shortening and a calcaneocavus deformity of the right foot (Figs 2, 3, and 4) His general condition was good Gastric washings and urine examination were negative for acid-fast organisms Blood chemistry and serology were within normal limits

On June 13, 1945, arthrodesis of the right knee was performed, the patella being used as a key graft, and a single hip spica was applied Recovery was uneventful and, after the sutures had been removed, a snug-fitting spica with an extension caliper was applied (to equalize limb length) and the patient was allowed to be up

On November 13, 1945 (five months after knee fusion), an amputation of the leg was performed (Figs 5 and 6) As soon as the wound was healed, a pylon and a peg-leg were fitted so that the patient might be ambulatory A prosthesis was then made and a rapid adjustment to it followed, in spite of the stiff hip, so that when the patient was discharged, on May 2, 1946, he was walking with an almost imperceptible limp, without support (Fig 7)

Knee fusion and later amputation of the leg to "equalize" the femora are indicated in growing children, rather than a Gritti-Stokes or supracondylar tendoplasty type of amputation. In this case, at the time the knee fusion was done, the patient was eleven years of age and had an expected five years of growth. Assuming cessation of growth on the affected side (the right lower extremity), the uninvolved femur would grow two and one-half inches at the knee while the tibia would grow one and two-thirds inches at the knee, making a total increased length of at least four and one-sixth inches by the time growth stopped, at the age of sixteen. We can assume that the amputated stump would be that much shorter if an above-the-knee amputation had been done originally. The procedure described would, therefore, give the patient a much more satisfactory stump and a much more satisfactory prosthesis at the time he reached maximum growth.

SUMMARY AND CONCLUSIONS

In the case described, a typical patient with tuberculosis of the hip, who was treated for a long time in traction and many plaster casts, with manipulation of the extremity under anaesthesia to correct apparent deformity about the knee, had two operations upon the hip with further immobilization. When fusion of the joint finally occurred, the extremity was 13.75 centimeters shorter than its normal mate, and a calcaneocavus deformity of the foot was present.

The method of treating such a useless and unsightly extremity includes the following steps:

1. Fusion of the knee joint;
2. Amputation of the extremity, so that the end of the stump will be at the same level as the knee joint of the "good" leg;
3. Fitting the patient with the proper prosthesis, after rehabilitation and training by prior application of a walking pylon.

The excellent result in the case described warrants serious consideration of this method of treatment for an extensively deformed and shortened lower extremity, resulting from damage to the susceptible epiphyses during so-called "conservative" treatment of hip-joint tuberculosis or other disease requiring prolonged immobilization of the lower extremity.

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A SUCCESSFUL PROSTHESIS FOR SACRO-ILIAC DISARTICULATION (HEMIPELVECTOMY)

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From the Surgical Service, Veterans Hospital, Portland

A satisfactory weight-bearing prosthesis for patients with sacro-iliac disarticulation has not, to our knowledge, been reported previously. Amputation through the sacro-iliac joint with removal of the ilium, ischium, and pubis sacrifices all weight-bearing areas considered essential to a lower-extremity prosthesis.

While only 138 cases of sacro-iliac disarticulation had been reported prior to 1945, the operation is now being performed more frequently. Many years of arrest may be anticipated, and have actually been achieved, by the removal of some of the malignant tumors of the innominate bone. It is unfortunate to condemn these patients to a life on crutches.

Such was the consideration when a left sacro-iliac disarticulation (Fig. 1) was performed on patient R. T., aged thirty-eight, for a primary osteochondrosarcoma of the left ilium.[1] This operation was carried out on July 21, 1947, at the Veterans Hospital, Portland, Oregon. The convalescence was smooth and the patient was up on crutches, three weeks after the operation (Fig. 2).

Construction of a walking prosthesis was initiated three months after the operation. The essential problems to be solved were two: first, what areas could be used for weight-bearing, with the ischial tuberosity and thigh-amputation stump missing; and second, how stabilization of the prosthesis could be achieved with absence of the iliac crest.

It was first considered necessary to have three points of weight-bearing: (a) the left axilla, (b) the opposite ischial tuberosity, and (c) the trunk and lower rib cage. Actually, after construction of the hip basket, it was found that full weight-bearing could be taken on the trunk, including the lower thoracic rib cage and the left wing of the sacrum, through the remaining segment of the gluteal muscles in the posterior portion of the amputation. The portion of the left gluteal muscles in the posterior flap remaining after the amputation proved to be of great aid as an area of weight-bearing and stabilization. It is suggested that as large a portion of these muscles as possible, consistent with a wide removal of the tumor, be spared. There was found to be only three-eighths of an inch upward movement of the basket during full weight-bearing. Therefore, no additional weight-bearing

FIG. 1

Roentgenogram, following operation for removal of the left innominate bone.

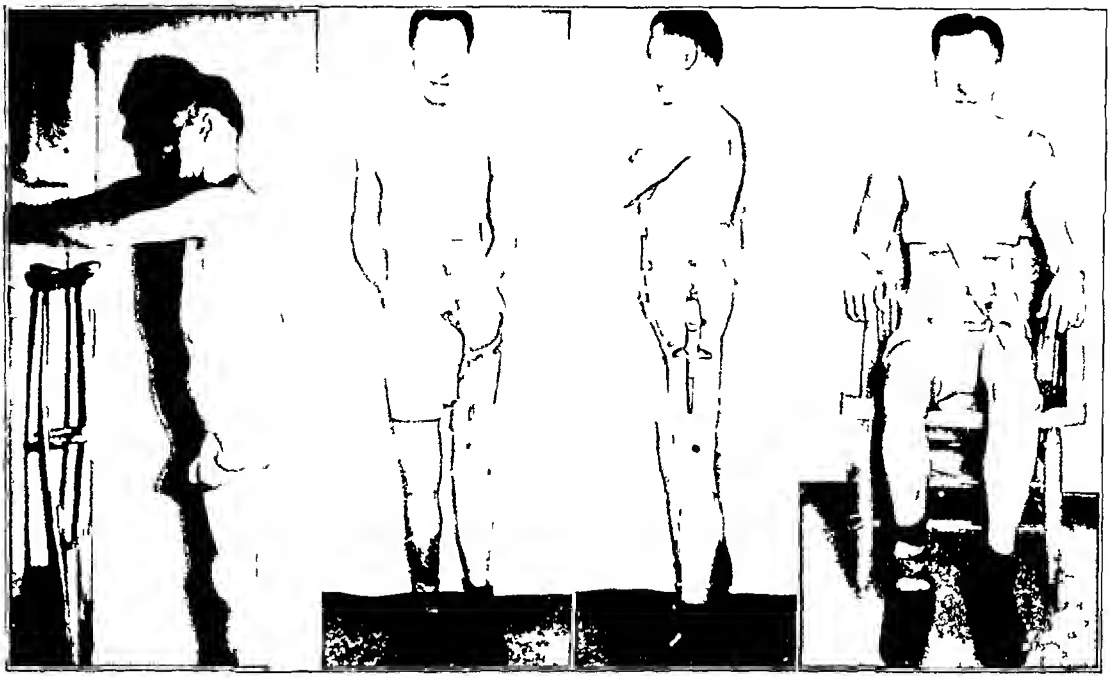

FIG 2 FIG 3 FIG 4 FIG 5

Fig 2 Photograph of the healed amputation wound (Reproduced, by permission of J B Lippincott Co, from Ann Surg, 128 996, 1948)
Figs 3 and 4 Anterior and lateral views of patient with prosthesis in place
Fig 5 View of prosthesis with patient in sitting position

points were necessary, obviating the need of an axillary crutch or an opposite ischial seat with the resultant restriction of trunk motion

The stabilization and alignment of the prosthesis were a major consideration Removal of half of the bony pelvis caused the lower trunk, opposite the remaining iliac crest, to assume a conical shape, making anchorage and alignment difficult It was necessary to construct a false buttock in order to obtain the normal width and length of the removed hemipelvis This portion of the prosthesis is made of balsa wood and cork, and is firmly anchored to the trunk portion by means of waterproof glue and rawhide (Figs 3 and 4) Its inner surface is in contact with the posterior flap of the amputation By construction of the trunk basket with buttock extension, stability and alignment were obtained in walking and sitting

The attachment of the extremity portion of the prosthesis to the hip basket was a normal prosthetic procedure The hip joint is furnished with a locking device, allowing flexion while the patient is sitting and locking in extension The axis of the knee is set posteriorly about one inch, preventing buckling of the knee in normal walking

The basket portion of the prosthesis is held around the trunk by three leather straps The knee-control strap extends over the opposite shoulder, produces extension of the lower extremity, and aids in anchoring the entire prosthesis to the body

The patient, when wearing the prosthesis, can walk with the aid of one cane He is able to walk up and down stairs, one step at a time, and can bend forward to touch his finger tips to the floor He can sit in normal position (Fig 5) and can kneel

NOTE Published with permission of the Chief Medical Director, Department of Medicine and Surgery, Veterans Administration, who assumes no responsibility for the opinions expressed or the conclusions drawn by the author

The author wishes to express his appreciation to Mr A W Pruhsmeier, brace-maker of Portland, Oregon, for his assistance in preparing the prosthesis described

1 WISE, R A Control of the Common Iliac Artery During Sacro-Iliac Disarticulation (Hemipelvectomy) Ann Surg, 128 993-998, 1948

MECHANICAL AIDS FOR PATIENTS WITH MUSCULAR DISABILITY

BY PAUL THOMAS YOUNG, PH D , URBANA, ILLINOIS

The writer has had experience with several cases of a rare form of muscular dystrophy in which there is a generally retarded muscular development With advancing age and increasing weight, the difficulty of locomotion is augmented Arising from a chair of ordinary height becomes an arduous task Going over stairs is laborious With one patient, if the rise is more than seven inches, the step cannot be mounted without assistance

To aid in meeting these difficulties, various mechanical aids have been evolved, through trial and error over a period of about thirty years The present report describes two forms of secondary aid,—stepping-stick canes and self-rising chairs

Stepping-Stick Canes

Figure 1 shows the evolution of a cane that is useful in negotiating steps which otherwise would be too high for the patient to mount without assistance The original form of stepping stick, shown at the left, consists of a broom handle to which a block of wood has been attached The block is three and one-half inches high and one and one-quarter inches thick, it is as wide as the patient's shoe In using this stick, the patient grasps the handle with the right hand and places the sole of the right shoe on the block, as with an ordinary stilt Then he lifts his weight to the block and swings forward, steadying himself with the handle The block has the effect of breaking a seven-inch rise into two rises, each of three and one-half inches

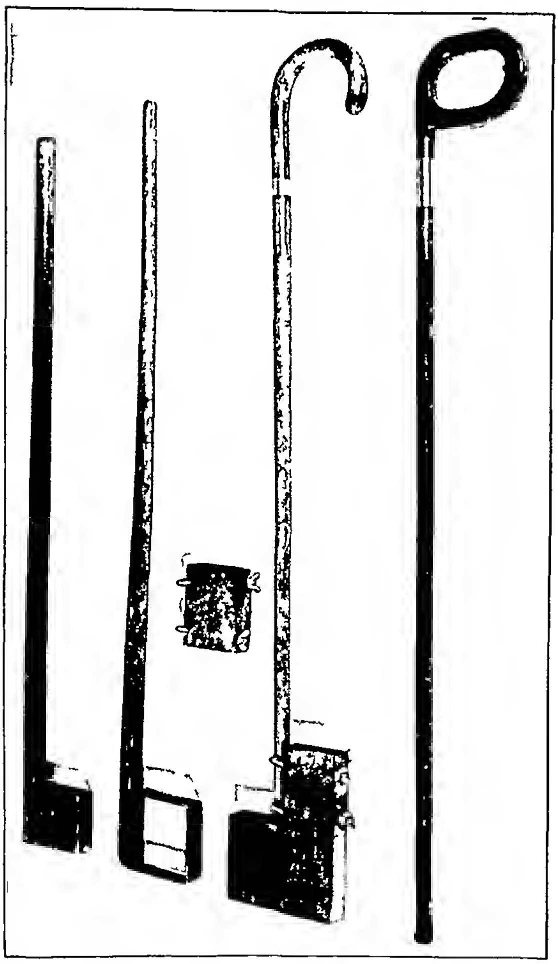

FIG 1

In the second cane from the left, instead of a block of wood, a square iron frame, made by a blacksmith, has been bolted to a light stick The stick is tapered, rounded, and made of suitable length When not in use as a stepping stick it can be turned upside down, and the square base becomes a handle

The third is an ordinary commercial cane to which blocks have been attached with butterfly nuts A single block (shown detached) can be clamped to the cane and quickly removed The block provides a step similar to that of the earlier models In the illustration a two-stage block is shown The first rise is three and one-half inches, the second is seven inches From a height of seven inches the patient can step up to a height of ten or eleven inches This two-stage block is useful, however, only when there is a railing or other means of steadying the body during ascent It has proved practical for a person getting on a train or making similar climbs

To give greater stability, a small aluminum ladder attached to a stick (not shown) has been made This is virtually a light-weight stepladder, made to suit the patient, which can be lifted from step to step by the handle One such ladder, now in use, has three steps

At the right of Figure 1 is an ordinary rubber-tipped cane with a painted head of aluminum alloy. This stepping stick resembles an ordinary cane, but, when turned upside down, the head can be used to enable the patient to negotiate a seven-inch step. The metal head can be unscrewed and a curved wooden handle inserted for use when the patient is walking on the level.

These devices make it possible for the patient to go over curbstones and steps which could otherwise not be climbed without aid.

Self-Rising Chairs

When the extensor muscles of the legs are too weak to lift the weight of the body from a sitting to a standing position, it is difficult for the patient to arise from a chair of ordinary height. However, he is able to walk on the level.

To meet this difficulty a small solid cushion, resembling a case, is placed on a chair. It is strong enough to hold the patient's weight and it raises the height of a chair about three inches,—just enough to make the difference between getting up with moderate ease and getting up awkwardly or, perhaps, not without help. The cushion is nine by twelve and one-half inches in cross section.

FIG. 2-A

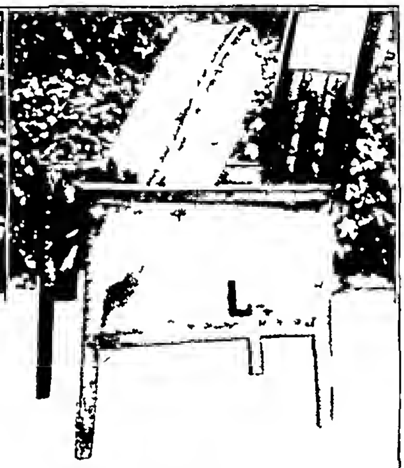

FIG. 2-B

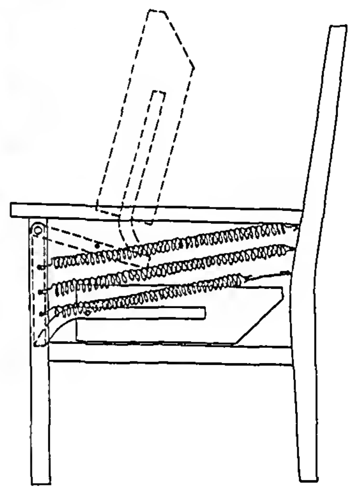

FIG. 3

In the home this problem has been solved differently. For ten years one patient with muscular dystrophy successfully used a special chair with a self-rising seat. Figures 2-A and 2-B show a dining-room chair made of quarter-sawed oak and leather. When the seat is lowered and locked (Fig. 2-A), the chair resembles an ordinary master's chair of a dining-room set. A spring mechanism, concealed in the sides by leather covering, lifts the seat to the raised position shown in Figure 2-B. A strong cupboard lock serves to hold the seat down, and this can be released by pulling a lever forward. The lever is shown at *L*.

As the patient places his weight against the raised seat, the seat lowers and steel extension springs in the side become tense. The tension counterbalances the weight of the patient, and in the lower position the seat can give an initial upward boost of about forty pounds, sufficient to enable the patient to arise with ease. The number of springs and the tension are, of course, varied to suit the requirements of the patient. The springs counterbalance the weight of the seat and much of the weight of the patient as he sits down. Upon arising, he literally springs to his feet.

Figure 3 shows the mechanical details of this chair, with the seat in the lowered position and the springs attached and stretched. The position of the seat, when raised, is indicated by broken lines. To swing the seat properly, two special iron braces are needed. As seen from the front with seat lowered, each brace resembles a J, one J turns to the right and the other to the left. The braces are pivoted at the top of the J and the exten-

sion springs are attached to the long vertical bar. In side view, one can observe that the lower tip of the J is curved upward and backward, so that it can be bolted firmly to the wooden frame of the seat.

Experimentation with several styles of self-rising chairs has brought to light an important principle. The rising seat should be pivoted as nearly as possible at the knee joint of the patient, or perhaps slightly in front and above the knee. In an unsuccessful model, the seat of an ordinary chair was hinged at the front edge. This seat, when partly raised, slid out from under the patient, leaving him suspended helplessly in mid-air. Thus, for mechanical reasons, the front edge of the seat must be several inches behind the front leg of the chair, as seen in Figures 2-A, 2-B, and 3.

In an overstuffed chair, extension springs, concealed within the sides, counterbalance the weight of the seat and enable the patient to spring to his feet from a comfortable seated position. A press button releases the lock mechanism which permits the seat to rise from the lower to the upper position. The seat can be locked down indefinitely, if desired, but this involves some risk, since a child can press the button to make the seat fly up and catapult whatever is upon it.

Possibly a self-rising chair would be serviceable to aged persons or to others who find it difficult to arise from a low chair or one of ordinary height. If the springs are carefully adjusted (and this can be done with a little trial and error), the self-rising chair easily and quickly brings the sitter to his feet.

At the present time no arrangements have been made for the manufacture of self-rising chairs and stepping-stick canes.

THE TREATMENT OF CONGENITAL CLUB-FOOT

Nine Years' Experience with a Modification of the Denis Browne Method and Splint

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During the past nine years many recurrences of congenital club-foot have clouded an earlier optimistic report[1]. These have not dampened our enthusiasm, because an analysis of these cases places the blame entirely upon the parents. Club-foot deformity is limited for the most part to the underprivileged classes, which adds a difficult personal element as far as treatment is concerned. In many of the cases of forthright parental neglect, our Social-Service Department discovered pitiful domestic conditions. In such instances foster homes were obtained, if possible. Failure to repair or replace dilapidated and outgrown apparatus was a common offense. In many of these cases, the families were large and underprivileged, care of the foot at home was often a hardship and, therefore, was not continued. Such parents were frequently ashamed to return to the Clinic. Strangely enough, return visits were made more regularly by those living far away than by those nearby. All these circumstances have prompted us to intensify the Social-Service inspection of the refractory cases. This has been aided by an appointment-card system with a rapid follow-up in case of failure to report.

In spite of the foregoing implications, numerous cases have presented difficulties during the course of treatment. The underlying cause of the trouble usually becomes evident after a few weeks. The most common of these cases are:

1. Mild types of myodystrophia foetalis, limited to the lower extremity and foot. When the extreme adduction has been corrected, a short, small, resistant foot is recognized, in which any correction is very slow and difficult.

2. Another similar type is a foot at first in severe equinovarus, which soon presents the added feature of a primus metatarsus varus. Such a condition may or may not have muscle involvement, but in either case correction is not the usual easy routine.

3. The neurogenic club-foot appears less frequently and shows motor and sensory changes. Occasional cases of this type of club-foot are corrected with amazing rapidity, only to become a potential calcaneovalgus deformity, while others of this type show a persistent tendency to recur. The bifid lumbar spine or the later growth of long fine hair over that area substantiates the diagnosis. Unusually sensitive trophic skin changes also lead to the suspicion of a neurogenic state.

4. Subluxation of the first metatarsophalangeal joint with dorsal displacement of the great toe is uncommon and of little trouble, and can be controlled by a pad under the head of the metatarsal. It usually becomes minimal at the walking stage.

5. A more common difficulty is the idiopathic club-foot of relatively small size, with a very large fat ankle and leg. This condition simply presents the mechanical problem of adhesive fixation over a deeply wrinkled ankle. Suitably placed small gauze pads help to control this type of case.

6. In a few cases an extremely flat foot has developed early in the treatment. In most of these cases, all treatment was stopped, in the hope that recurrence would not take place, but deformities recurred in all but a few instances.

Such examples depict a few irregularities which help to remind us that equinovarus deformities may have many inherent differences. In most cases these defects are difficult to detect at onset and become evident only after a few weeks of treatment. The hip and

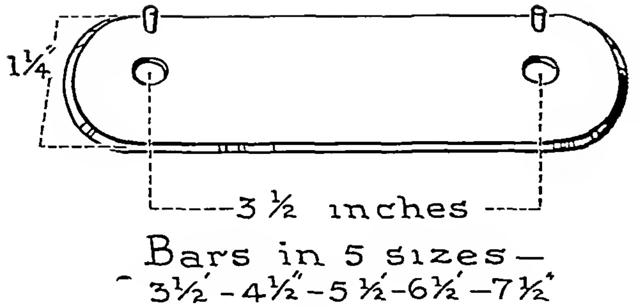

Fig 1

knee joints must be normal if the splint is to achieve its purpose Club-foot is an outstanding example of a condition that requires a unified continuity of attention from both surgical and technical staffs, if favorable results are to be obtained The moment that casual supervision is allowed, recurrences begin to soar

A few modifications in treatment are worthy of mention

1 The length of the crossbar has been considerably shortened and now conforms to the distance between the hips (Fig 1) This was done in order to overcome numerous cases of refractory varus Additional correction was also obtained in such cases by keeping the foot piece fixed at one hole less than a right angle In that position, valgus movements, as well as dorsiflexion, may be performed Bending of the crossbar may occasionally be required in a sick child who does not actively kick or crawl

2 The foot plates are now made to fit the average foot more snugly An undersized plate will stay on better than one that is too large Foot plates are made in four sizes and are covered with sponge rubber The first three sizes will usually suffice until the boot-splint stage is reached The plate sizes are shown in Figure 2 before the upright portion has been bent

3 The boot splints are no longer made to order, because of the time and expense required A small pair of baby boots are fitted, then the simple adjustments are fastened to a reinforced sole, and the toe cap is removed Therefore, the child does not reach the boot-splint stage quite so early as formerly, because accurate fitting is difficult in a small foot The same proportionately short crossbar is used with the boot splints, which are kept on day and night During the child's second year—the beginning of the walking period—splints are used at night, and are also applied for long periods during the day for exercise If the foot appears to be essentially normal and no tendency to recurrence is evident, the foregoing regimen may be modified and finally abandoned If, however, any club-foot stigmata remain—such as limitation of full dorsiflexion or varus—a strict and pro

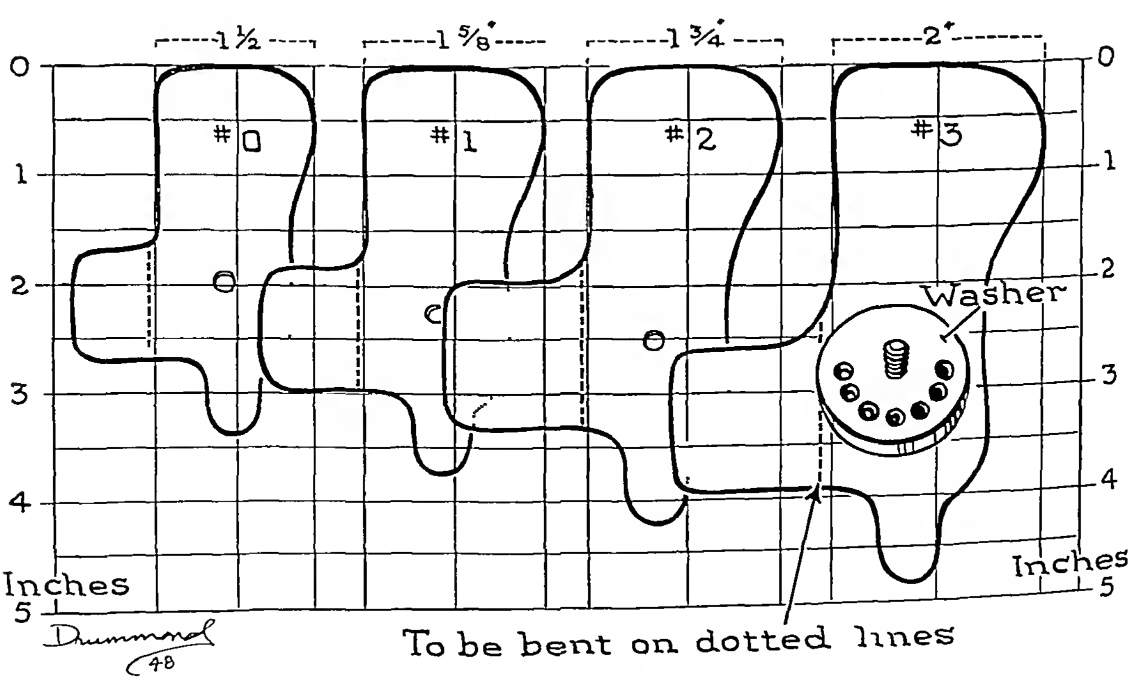

Fig 2
Foot-plate patterns

longed application of the boot-splint is recommended, the use of the walking boots being allowed for only a few short periods a day. It may be necessary to continue this care well into the third or fourth year of life. Whenever the boot splints are used, the parents are urged to manipulate the foot daily.

4. The spring splint[2] has been simplified (Fig. 3) by elimination of the adjustable swivel, which occasionally gave trouble when the child was going down steps. This splint has done much to compensate for the negligence of the parent, since it replaces not only the boot splint, but also the need for daily manipulation. It is, therefore, occasionally used on a well-corrected foot, where parental neglect is feared. The usefulness of this splint decreases with the age of the child and is of doubtful value in the average-sized child after seven to eight years of age. Bob-skating, ice-skating, roller-skating, and skiing are urgently prescribed as a daily routine, since these sports all require dorsiflexion.

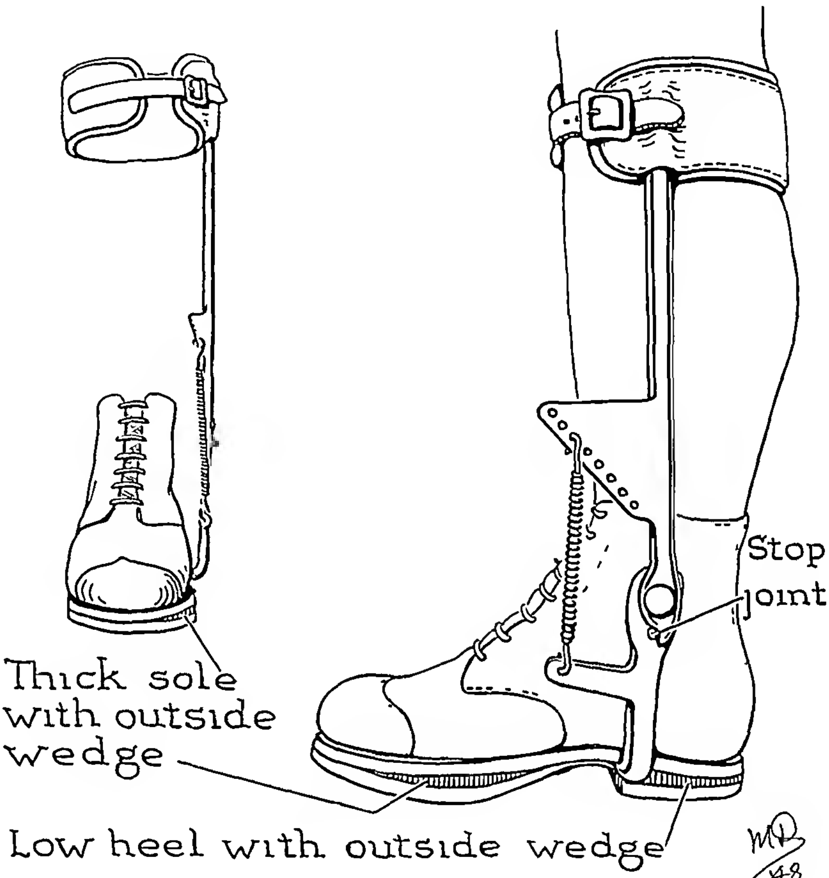

Fig. 3
Spring splint

Recurrences begin to appear as soon as the parents are asked to share more responsibility in the care of the feet, beginning at the boot-splint stage and increasing at the walking period. Thus, the incidence of good results varies directly with the intelligent cooperation of the parents. Recurrences which limit dorsiflexion to a right angle or better can be controlled and improved by rigid application of the boot splints. However, a recurrence which will not allow passive dorsiflexion of the foot as far as a right angle with the leg will not be amenable to the boot splint. In these cases the Denis Browne splint must again be used, with adhesive fixation. This can be done until about two years of age, but is not very successful after that time, because of pressure effects, due to the combination of a more resistant foot and a more active child. It may then be necessary to resort to manipulation and the application of a plaster cast at one or more sittings. When the recurrence has been partly or fully overcome, the boot splint may be re-applied. In the past two years, it has been deemed wiser to apply the spring splint, because it provides double assurance against these chronically careless parents.

During the past nine years, 260 cases of idiopathic equinovarus deformities have been treated with the Denis Browne splint. We continue to be highly pleased with this method and, by and large, we obtain uniformly good results. The deformity is corrected in six to eight weeks without manipulation, and the foot and leg take on a remarkably normal appearance. In such cases, no recurrence or complication is anticipated, if the doctor and

parent keep their faith and the child remains healthy If complications arise, they usually become evident during the initial two months of correction, when a revised diagnosis and treatment may be necessary

During the past two and three-quarters years, since the spring splint has been in use, a better check has been kept on frank recurrences Forty children in the group have been supplied with spring splints, which represents a recurrence rate of approximately 15 3 per cent Many of these children had not returned to the Clinic for many months or years, while other recurrences were detected earlier If the early cases, in children under one year of age, are left out of the total, the recurrence rate is approximately 17 per cent

REFERENCES

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2 THOMSON, S A A Splint for Treatment of Recurrent Club-Foot J Bone and Joint Surg , 28 778-779, Oct 1946

UNIVERSAL SPLINT FOR HIP MOTION *

BY PAUL C THOMPSON, M D , SWANNANOA, NORTH CAROLINA, AND JAMES H CHERRY, M D , ASHEVILLE, NORTH CAROLINA

From the Division of Orthopaedic Surgery, Swannanoa Division, Veterans Administration Hospital, Oteen, North Carolina

It is generally agreed by most orthopaedic surgeons that the end results of Vitallium-cup arthroplasty depend to a great extent upon the patient's will and determination to regain hip motion following surgery, with the assistance of physical therapy This fact has led the authors to devise a universal splint for the lower extremity The apparatus can be easily adjusted to fit all sizes and shapes of limbs, and is of such simplicity that it can be applied or removed within several minutes

This splint (Figs 1 and 2) has a knee bend without a lock and a foot piece to which the shoe can easily be attached The foot piece rests on two rollers, two and one-quarter inches in size, which permit motion in all directions With the patient in the proper position and a small fracture board in place across the lower third of the bed, the splint can be moved in any direction on the board By the manipulation of two ropes with pulleys and hand attachments, the patient can secure any form of hip motion Figure 1 demonstrates the mechanism for securing free ankle and knee motion Figure 2 shows the limb in abduction, secured by manipulation of hand attachments, the patient can actively bring the limb into abduction

* Published with permission of the Chief Medical Officer, Department of Medicine and Surgery, Veterans Administration, who assumes no responsibility for the opinions expressed or the conclusions drawn by the authors

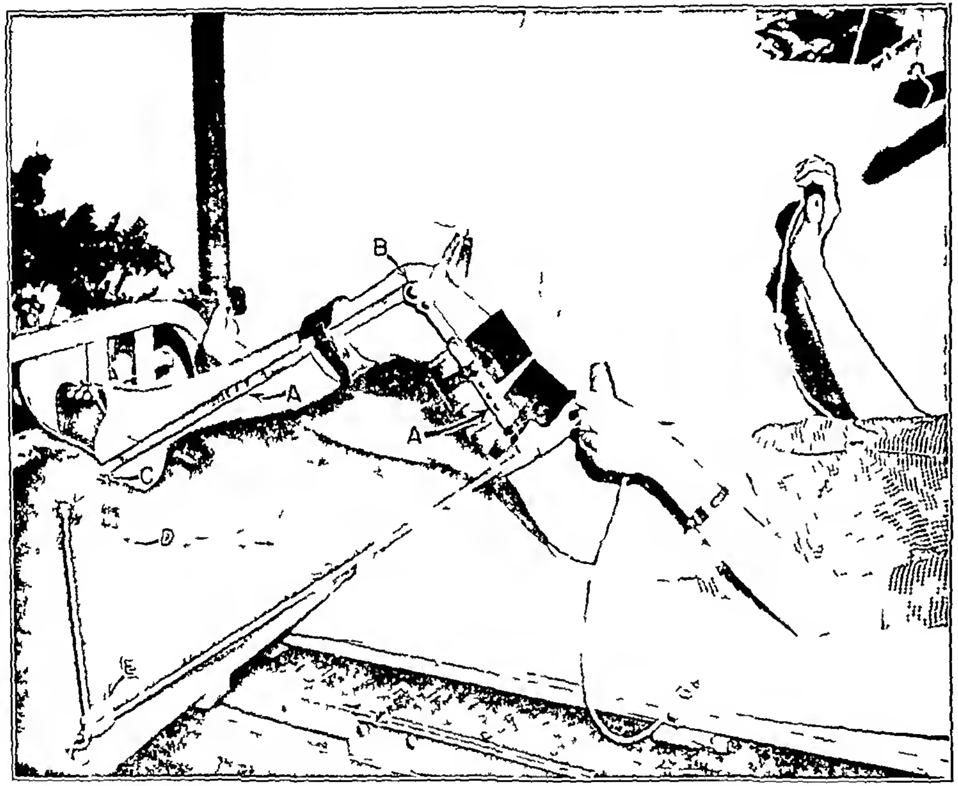

Fig 1

Fig 1 Lateral view of universal splint, demonstrating the mechanism for securing free ankle and knee motion
A Adjustable length mechanism
B Knee bend to permit free knee motion
C Caliper plate to afford free ankle motion
D Two and one-quarter-inch rollers
E Pulley

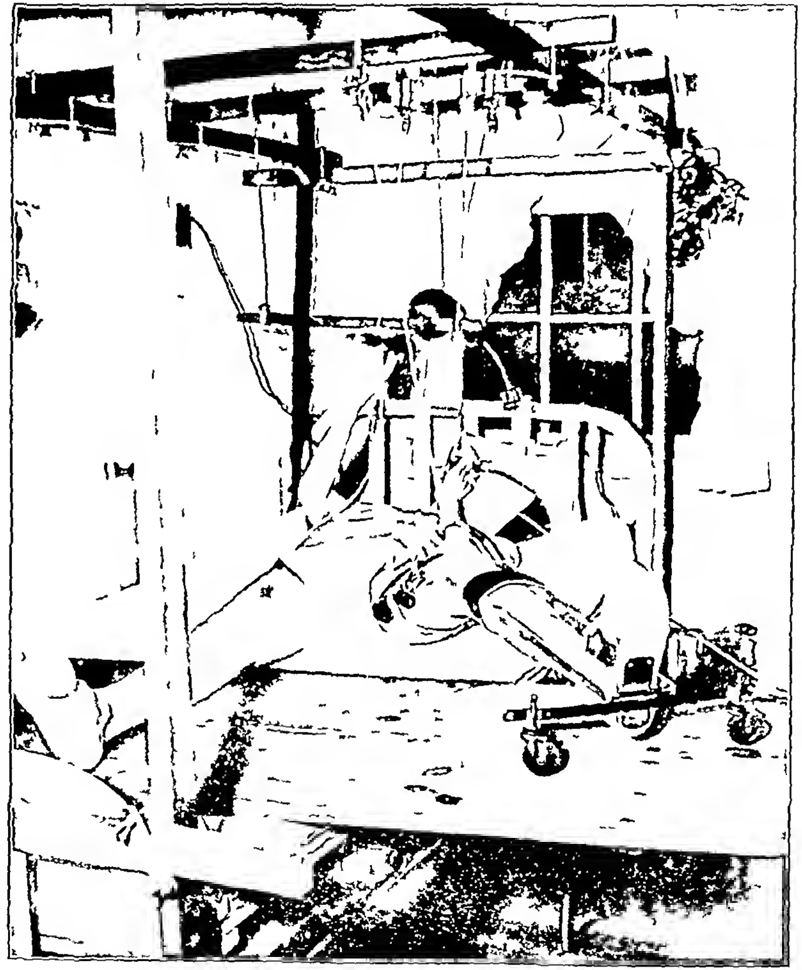

Fig 2

Fig 2 Anterior view shows how, by manipulation of apparatus, patient has brought leg into abduction Ropes and pulleys can be arranged to obtain lateral and medial *motion, as needed*

Postoperative treatment following Vitallium-cup arthroplasty of the hip at this Hospital consists of immobilization in a unilateral hip spica with the lower extremity in abduction and internal rotation for a period of three weeks Following this, the cast is removed and a universal splint is applied The splint is worn throughout the day, except for one hour in the morning and another in the afternoon when physical therapy is instituted At night the splint is removed and Buck's traction, with approximately five pounds of weight, is applied

The results in this Hospital in regaining hip motion by the use of this universal splint have been excellent The splint has met with enthusiastic response on the part of the patients, who find that they are able to secure voluntary active and passive motion and to regain a wider range of motion of the affected limb than is possible with other types of mechanotherapy or with physical therapy alone

NOTE The authors wish to acknowledge the assistance of Mr W A McElduff, Asheville, North Carolina, in the construction of this splint

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A SPINE RETRACTOR OF SIMPLE CONSTRUCTION

BY WERNER P JENSEN, M D , OMAHA, NEBRASKA

The perfect spine retractor has yet to be made Usually the muscle slips from under the retractor blades, the retractor itself does not remain in place, or the retractor opens only after a great deal of effort

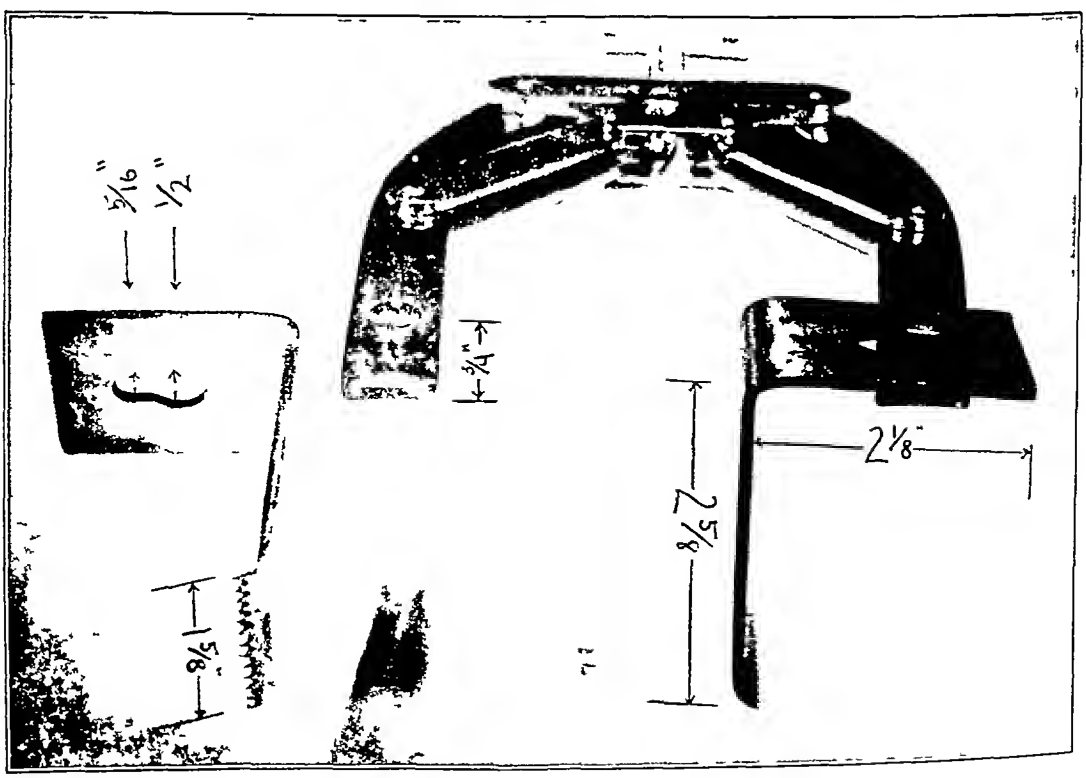

FIG 1

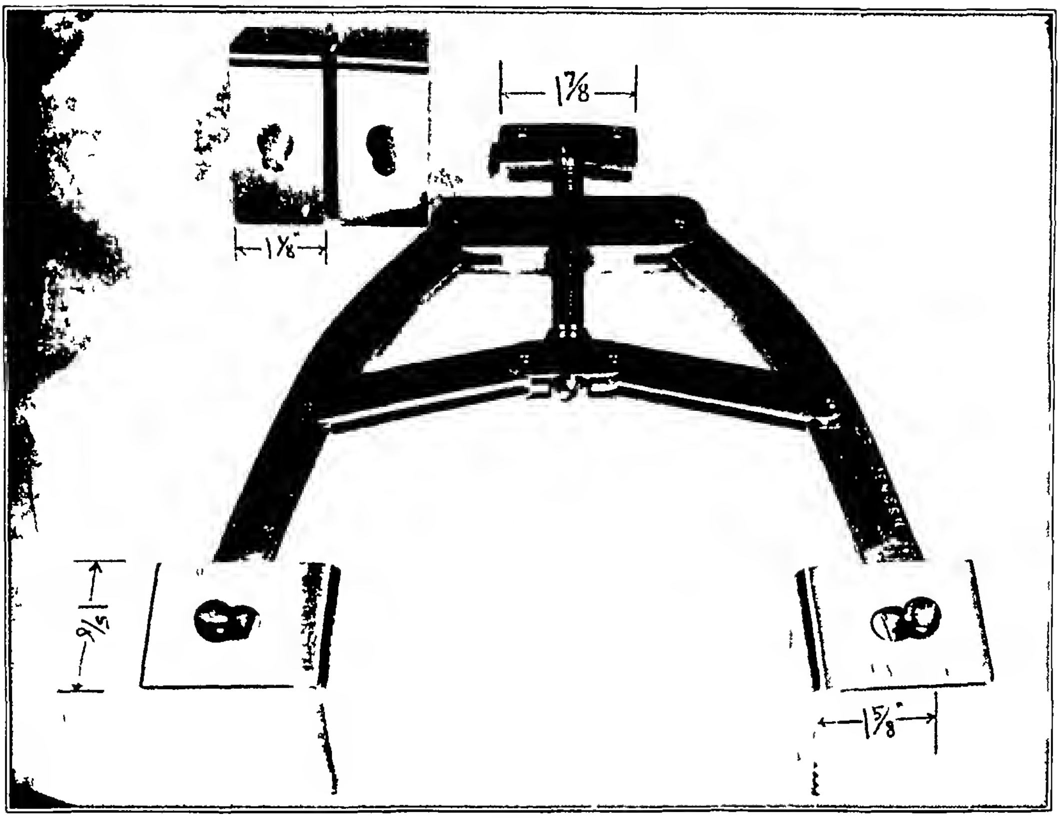

Fig 2

The retractor pictured (Figs 1 and 2), when placed in position and opened, holds the spine muscles so that the lamina and articular facets are readily accessible The motor of the retractor is a medium-sized Kirschner clevis That pictured was obtained from war-assets surplus The blades are made of stainless steel, patterned after Hibbs' spine retractors, and have proved satisfactory The design of the blades may be changed to suit individual requirements The blades touch when the clevis is closed and may be spread apart to give an opening of five and one-half inches, which is more than is ever required

In making the retractor, the movable portions of the wire-holding jaws of the clevis were removed and the two ends were made flat by polishing on a grindstone A five-sixteenths-inch bolt with a half-inch head was then secured, three-quarters of an inch from the end of each arm The turning handle of the clevis was cut down with a hack saw to one and seven-eighths inches This permits easy opening of the blades without tilting of the retractor, and ample leverage is still retained

The blades of the retractor were easily made, with the use of a drill press, vise, hack saw, file, and grindstone The teeth were cut with a file The stainless steel bends easily without being heated The wider blade, of the two pictured, has been used most frequently

Note Acknowledgment is made to Mr Earl Rodgers, brace maker at Shriners' Hospital for Crippled Children, Shreveport, Louisiana, for his help and suggestions, and to Wynton H Carroll, M D, Senior Resident in Radiology at Charity Hospital, Shreveport, for the photographs

AN ABDUCTION EXERCISE SPLINT FOR THE SHOULDER

BY EDWARD J COUGHLIN, JR, M D, WILLIAMSTOWN, MASSACHUSETTS

In many lesions in and around the shoulder joint, abduction within certain limits is greatly to be desired Unfortunately, this has not been possible in many instances without keeping the patient confined to bed in some form of balanced suspension From an economic point of view, this is burdensome, and at the present time, with hospital beds at a premium, it is impossible In an attempt to provide abduction exercises without hospitalization, the ambulatory splint was devised

The idea of this splint is not original with the author A crude abduction apparatus was first seen by the author in a prisoner-of-war camp in southern France The original splint consisted of a plaster-of-Paris cuirass into which was incorporated a metal U-shaped bar, at the tip of this bar a pulley was attached The author's first modification was to make the cuirass of castex with laces, so that it could be removed at night, and the splint illustrated here is the final outcome of this modification

The splint consists of a U-shaped metal bar which is strapped to the body by means

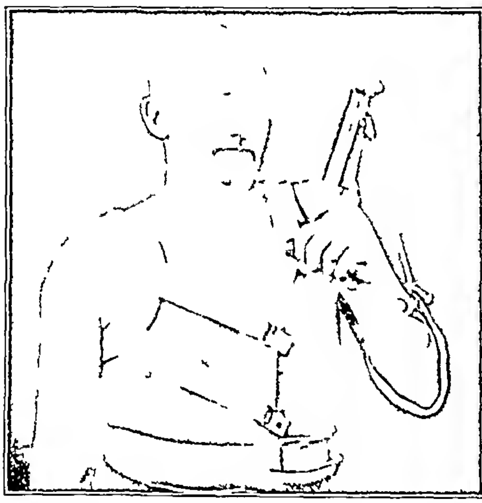

FIG 1

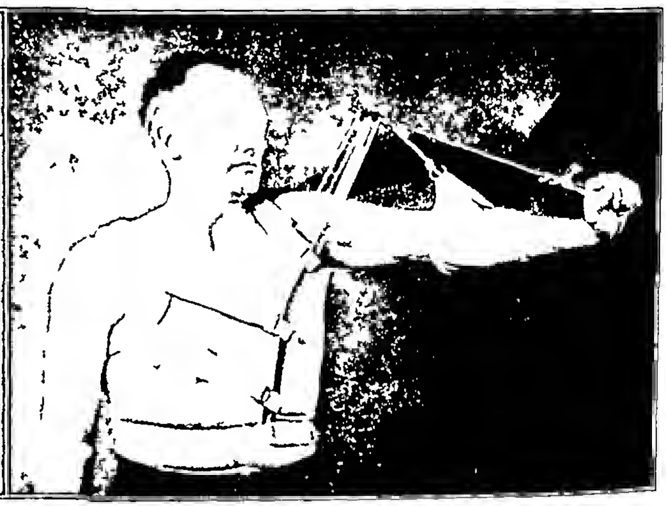

FIG 2

of cross straps, and an axillary ring on the opposite side In addition, there is a shoulder strap on the affected side to prevent the shoulder from being elevated during the period of abduction (Fig 1) The principle underlying the splint is very simple Extension of the elbow shortens the rope from the elbow to the pulley (Fig 2), and by means of the sling around the elbow, the arm is brought into abduction The degree of abduction to be obtained may be varied by shortening or lengthening the rope extending from the elbow sling to the hand grip

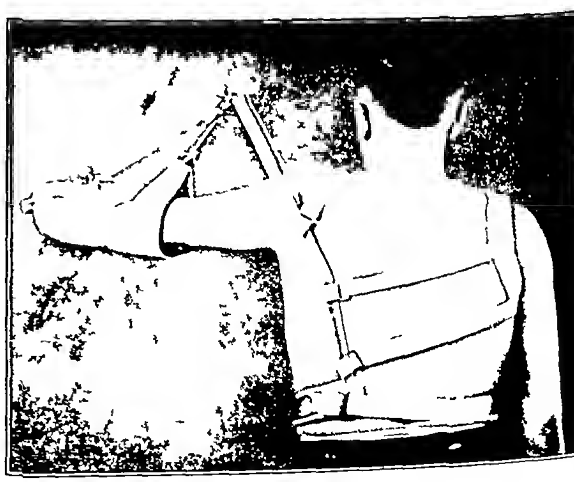

FIG 3

The use of the abduction exercise splint is especially indicated in the following

1 *Subdeltoid Bursitis* The author has used the abduction exercise splint on several patients with acute subdeltoid bursitis, following novocain injection and lavage of the bursa

2. *Calcification in the Supraspinatus Tendon.* By the use of the abduction exercise splint, the patient with calcification in the supraspinatus tendon is able to be ambulatory immediately after operation and to carry out abduction exercises with little or no discomfort.

3. *Exercise for the "Frozen Shoulder."* The use of this splint will enable immediate active motion through a wide range and with a considerable degree of comfort.

4. *Lesions of the Musculotendinous Cuff.* By means of the active abduction splint, used postoperatively, the arm can be abducted as much as 90 degrees with no danger of disturbing the suture line of the repair of the musculotendinous cuff.

5. *Fractures.* Following impacted fractures or in fractures of the greater tuberosity where graded amounts of abduction are desirable, the splint may be used to encourage motion within a limited range, since by lengthening the abduction cord any degree of abduction desired can be obtained. Of course, the splint should never be used when there is any danger of disimpacting fragments or in shaft fractures where angulation would inevitably occur. It should be used only for patients who would otherwise be receiving relaxing and circumduction exercises.

6. *Nerve Lesions.* The author has used the abduction splint on several cases of axillary-nerve paralysis, following dislocations of the shoulder, with extremely gratifying results. On two occasions, the splint has been used in poliomyelitic patients with involvement of the abduction mechanism. By the use of the abduction splint with resistance, the power of a partially paralyzed deltoid has been increased so that active abduction was possible.

NOTE: The author is indebted to Carl Ramminger of the Hospital for Special Surgery, New York, N. Y., for his cooperation in constructing the abduction exercise splint.

A RIGID PLASTIC CORSET FOR ARM AND LEG BRACES

BY LIEUTENANT COLONEL MILTON S. THOMPSON, *Medical Corps, United States Army,*
AND CAPTAIN REX J. HOWARD, *Medical Corps, Army of the United States*

From the Orthopaedic Service, Brooke General Hospital, Fort Sam Houston, Texas

In certain patients with ununited fractures of long bones, delayed union of fractures, loss of bone substance, or old infections of bone, rigid fixation of the extremity is essential to prevent deformity, and ambulation is desirable. Casts and traction will provide the necessary rigidity, but these prevent ambulation. The common type of ischial weight-bearing brace permits ambulation, but it fails to provide the necessary rigidity in some instances. To solve this problem, a brace has been developed which incorporates the

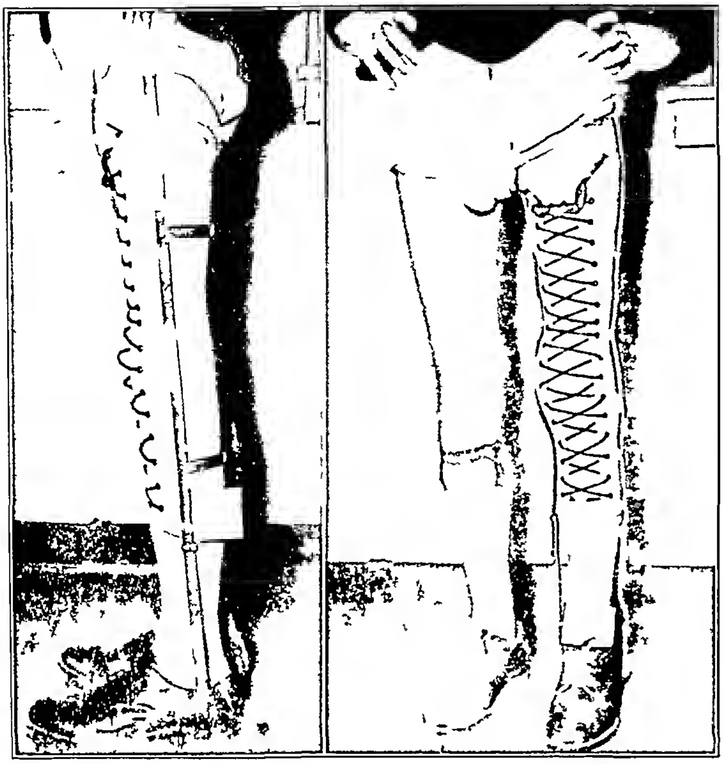

FIG. 1-A FIG. 1-B

Fig. 1-A. Lateral view of corset, incorporated into an ischial weight-bearing brace.
Fig. 1-B. Anterior view of corset and brace.

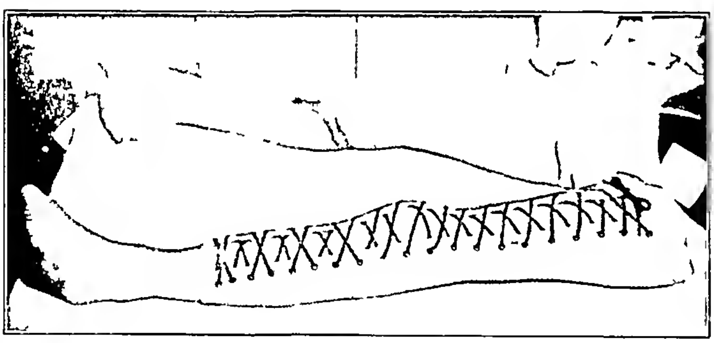

FIG. 2

Corset used as night splint.

rigidity of a plaster cast into a brace and which at the same time enables many of these patients to become ambulatory (Figs. 1-A and 1-B).

A positive plaster mold of the extremity is made. This mold is then covered with horsehide, the edges of which meet anteriorly in a vertical line. The leather is fastened with tacks, and one coat of a cellulose cement, which is soluble in acetone, is applied and allowed to dry for twenty minutes. Then, a piece of celastic, the size of the horsehide cover, is dipped into acetone; when saturated, the celastic becomes completely limp and pliable. The leather is dampened with acetone and the piece of celastic is quickly molded to it, wrapped with an elastic bandage, and allowed to dry for four or five hours. Another piece of horsehide is then placed over the celastic with the cement. This is also allowed to dry for four or five hours. The edges are then trimmed and bound with horsehide. Eyelets are inserted along the anterior gap, approximately one and one-fourth inches apart, and one half inch back from the edge. Laces are inserted, and the molded splint is complete. This splint may be easily incorporated into a brace (Figs. 1-A and 1-B).

The authors have used celastic in braces for both the lower and upper extremities. Moreover, it is used by the Army in making sockets for artificial limbs. It can also be used in shoulder caps for shoulder disarticulations, in inner soles for partial-foot amputations, in night splints (Fig. 2), and for many other orthopaedic appliances. It is light, strong, easily molded, and highly suitable, therefore, for making snug-fitting splints for the extremities.

NOTE: Acknowledgment for the technical details of this brace is made to Arthur D. Salmon, Chief Orthopaedic Mechanic, Brace Shop, Brooke General Hospital.

A LUMBOSACRAL SUPPORT

BY REX L. DIVELEY, M.D., KANSAS CITY, MISSOURI

It is frequently necessary to provide support to the lumbosacral region or the lower lumbar segments of the spine. This is accomplished relatively simply in female patients by the incorporation of a light steel brace in a properly fitted front-lace corset. In male patients the problem is more difficult, as most low-back braces are uncomfortable to wear and they often fail to give adequate immobilization to the lumbosacral area.

To solve this problem for the male patient, a so-called lumbosacral belt has been developed, which has been used with gratifying results. This belt has proved efficient in the treatment of acute lumbosacral strain or sprain, in lumbosacral arthritis, in the postoperative care of lumbosacral fusion, and, in fact, in any condition in which immobilization of the lumbosacral joint or the lower lumbar spine is desired. This type of belt also gives satisfactory support to a man with a pendulous abdomen.

Our bracemaker carries in stock four sizes of lumbosacral steel frames, seven, eight, nine, and ten inches in height (Fig. 1). The appropriate style of steel frame, which should extend from the body of the sacrum as far up the lumbar spine as immobilization is desired (generally the second or third lumbar vertebra), is selected and carefully fitted to the curve of the back with bending irons (Fig. 2).

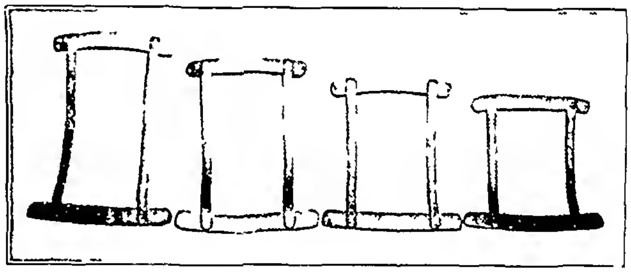

FIG. 1

Steel frames, varying from seven to ten inches in height, for lumbosacral support.

For the female patient, this steel is incorporated into a properly fitted front-lace corset. For the male patient, the steel is fitted into a duck belt which is held in place by three or four straps with buckles. Two additional reinforcing straps attached to the steel, one above and one below, hold the steel firmly against the back (Figs. 3 and 4). This belt will usually stay in place quite satisfactorily, but, if it tends to ride upward, peroneal straps can be added.

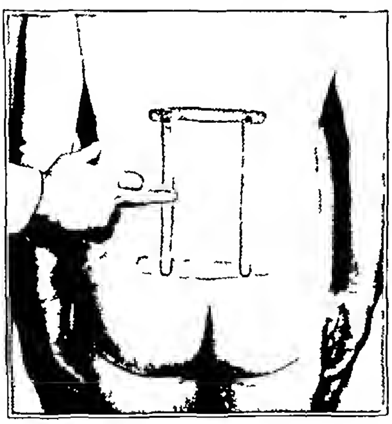

FIG. 2

Brace fitted to curve of back.

FIG. 3 FIG. 4

Front and back views of support, applied to patient.

ADAPTATIONS OF THE SURGICAL ENGINE

BY DANIEL M STIEFEL, M D , DETROIT, MICHIGAN

From the Department of Orthopaedic Surgery, Grace Hospital, Detroit

A simple adaptation of the widely used Luck saw or surgical engine has proved useful to the author It has become increasingly apparent that the dentist's armamentarium contains a number of devices which can be used with good results in orthopaedic surgery This is especially true of a short drill in a dental handpiece, which can be used in drilling the glenoid rim in the Bankart operation

To adapt the dental handpiece to this surgical engine, a flexible shaft is used to transmit power to the drill in the dental device The shaft may be easily attached to the Jacobs chuck of the engine by inserting a short quarter-inch rod into the motor end of the shaft The tool end of the shaft is furnished with two interchangeable collets with capacities from zero to one-quarter of an inch The flexible shaft is four feet long, and the handpiece of this shaft is one and one-quarter inches in diameter

A simple stand for the engine is constructed from a metal plate To this is attached a cradle of bent bands of steel Passing over the engine, pieces of so-called "power chain" encased in rubber tubing hold it in place on the cradle One end of each chain is fixed to an end of each member of the cradle on one side The other ends of the chains, each bearing a wing nut, are fastened to the opposite sides of the two cradle members When in use, the cradle stand holds the engine and is placed on a small instrument table The motor end of the sterile flexible shaft is handed to a nurse, who fastens it into the Jacobs chuck with the key in the usual manner Neither the engine nor its electrical connections are sterilized when used in this adaptation A small sterile sheet is thrown over the table and engine, and a fold of the sheet is loosely caught around the proximal end of the shaft with a towel clamp

The adaptor and driver, which are used to drive a tool in a dental handpiece, are shown in Figure 2 Figure 3 shows the assembled apparatus

The adaptor is a stainless-steel shell which fits over the distal end of the flexible shaft This adaptor is held in place by a recessed screw, which pierces the shell near its lower rim and is tightened against the shaft end The dental handpiece is thrust into the hollow neck of the adaptor and is held in place by tightening the ring nut over the slightly conical end of the slotted neck The inserted tube is thus grasped by collet action As an added safe-

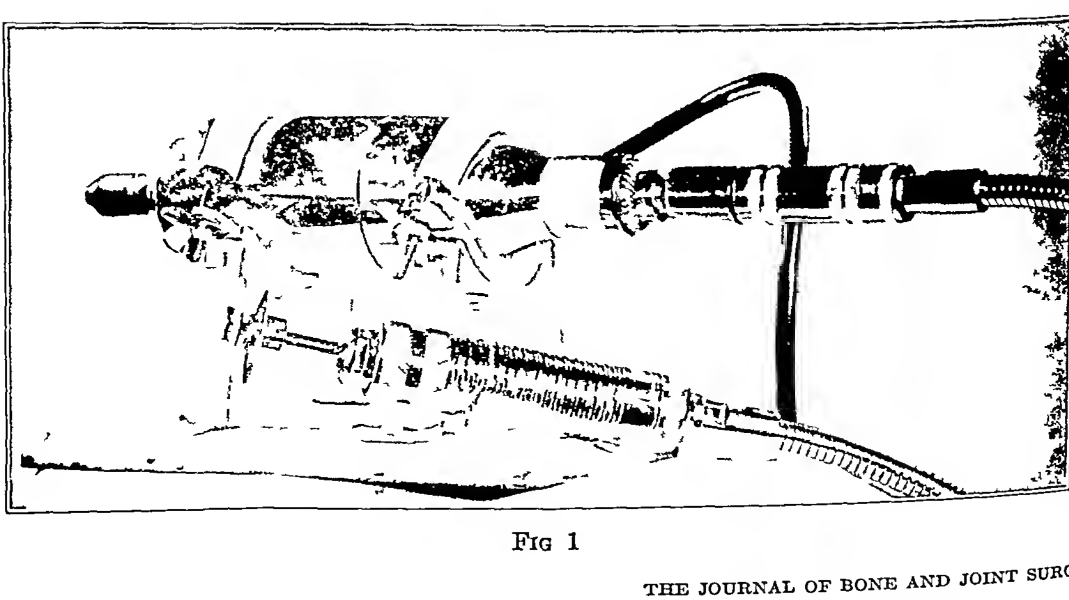

FIG 1

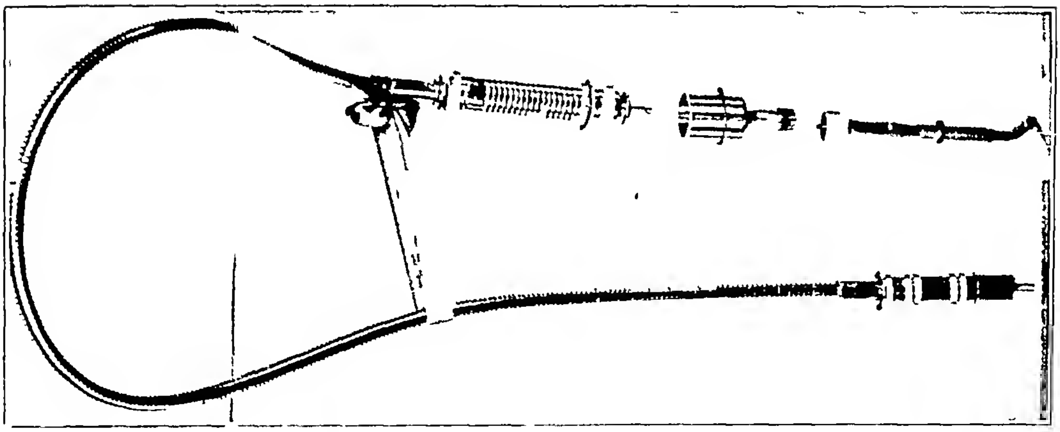

FIG 2

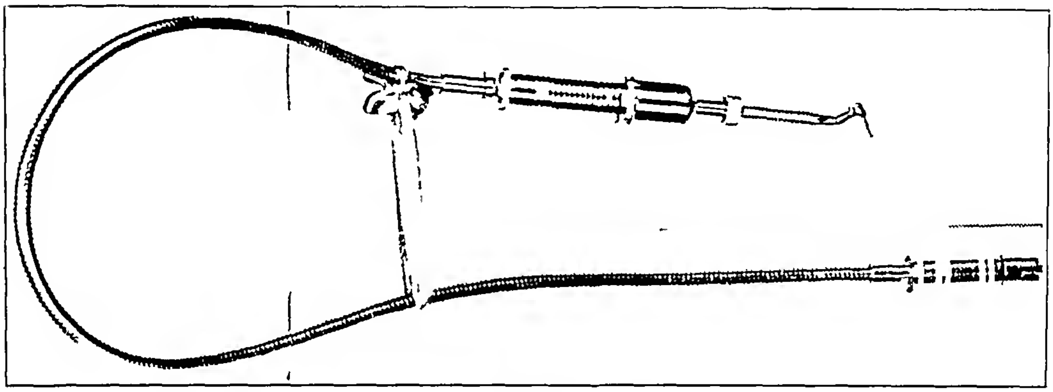

FIG 3

guard against rotation of the dental handpiece, a recessed screw pierces the adaptor at the base of the neck and enters the slot in the lower end of the handpiece

The driver of the dental instrument consists of a rod with an inverted notch which, in dental practice, engages with a coupling carrying a similar notched rod in the motor apparatus In this adaptation, a short length of rod is similarly notched and is furnished with a shoulder, so that it will insert to a constant depth, the rod is then placed in the collet end of the flexible shaft When the adaptor with its dental handpiece is fitted over the end of the flexible shaft, the two notched rods will readily mesh and power can be transmitted to a tool in the end of the dental device

All standard dental metallic burrs and tools used with such a handpiece may also be used in surgery For use in drilling bone for the passage of sutures, the author has had standard 3/32-inch twist drills cut down to lengths of one and of one and five-tenths centimeters, respectively, with the proximal ends appropriately notched to fit into the dental handpiece

As seen in Figure 1, the shaft can also be used to drive the regular saws and drills usually attached directly to the engine chuck The engine can easily be taken from its stand for other uses

NOTE The writer wishes to acknowledge valuable technical advice and help in the construction of these adaptations given by Mr Fred Walton of Detroit

News Notes

THE AMERICAN ORTHOPAEDIC ASSOCIATION

The Sixty-second Annual Meeting of The American Orthopaedic Association will be held at the Broadmoor, Colorado Springs, Colorado, on May 18, 19, 20, and 21, 1949, under the presidency of Dr Ralph K Ghormley

The orthopaedic surgeons of Denver, with Dr Robert G Packard and Dr Atha Thomas as chairmen, have planned a Clinical Day in Denver on May 17 All members of the Association and their guests are invited Those planning to attend are requested to notify Dr Packard or Dr Thomas in advance, so that adequate arrangements may be made

The tentative program of the Meeting, as submitted by the Program Committee, is as follows

WEDNESDAY, MAY 18

Morning Session

Osteochondromata Arising from Articular Cartilage
James Vernon Luck, M D, Los Angeles, California (by invitation)

Correction of Deformity and Prevention of Aseptic Necrosis in Late Cases of Slipped Femoral Epiphysis
Edward L Compere, M D, Chicago, Illinois

Congenital Dislocation of the Hip with Particular Reference to its Pathogenesis—Treatment by Open Reduction and Results
Beckett Howorth, M D, New York, N Y

Extra-Articular Fusion of the Hip
George W Van Gorder, M D, Boston, Massachusetts

A New Technique for Arthrodesis of the Hip
Alan DeForest Smith, M D, New York, N Y

Trials and Tribulations in Attempted Femoral Lengthening
H Relton McCarroll, M D, St Louis, Missouri

Noon Executive Session

Afternoon Session

A Conference, sponsored and arranged by the Joint Committee on Postgraduate Education of The American Orthopaedic Association and The American Academy of Orthopaedic Surgeons

1 Introductory remarks by the Chairman
A R Shands, Jr, Alfred I duPont Institute, Wilmington, Delaware

2 The Ideal Curriculum
A For Adult and Fracture Training
Alan DeForest Smith, M D, New York Orthopaedic Hospital, New York, N Y
B For Children's Training
William T Green, M D, Children's Hospital, Boston, Massachusetts
C For Basic-Science Instruction
Guy A Caldwell, M D, Tulane University, New Orleans, Louisiana

3 The Ideal Curriculum of Resident Training in
A A University Clinic
Carl E Badgley, M D, University of Michigan, Ann Arbor, Michigan
B A Private Clinic
J Spencer Speed, M D, Campbell Clinic, Memphis, Tennessee

4 Resident Training in a Government Hospital
A Veterans Administration
Dana M Street, M D, Kennedy Veterans Hospital, Memphis, Tennessee
B United States Army
Lieutenant Colonel Milton S Thompson, M C, Brooke General Hospital, Fort Sam Houston, Texas

5 Special Training the Resident Should Have in
A Cerebral Palsy
Robert A Knight, M D, Campbell Clinic, Memphis, Tennessee
B Infantile Paralysis
R E Lenhard, M D, Johns Hopkins Hospital, Baltimore, Maryland
C The Fitting and Making of Braces and Prostheses
Atha Thomas, M D, Denver, Colorado

6 Special Training the Resident Should Have in
A Related Subjects Physical Medicine, Roentgenology, Neurology, and Rheumatology
B Research and Publications
Fremont A Chandler, M D, University of Illinois, Chicago, Illinois
7 The Graduate School of Medicine Course in Orthopaedic Surgery and Its Curriculum
J T Nicholson, M D, University of Pennsylvania Graduate School, Philadelphia, Pennsylvania
8 What Constitutes a Satisfactory Preceptorship Training
J Albert Key, M D, Washington University, St Louis, Missouri
9 Comments from The American Board of Orthopaedic Surgery on Board Certification and Resident Training
Francis M McKeever, M D, Los Angeles, California
10 The American College of Surgeons and Specialty Training
P D Wilson, M D, The Hospital for Special Surgery, New York, N Y
11 The American Medical Association and Specialty Training
F H Arestad, M D, Council on Medical Education and Hospitals, Chicago, Illinois
12 Discussion and Summary

THURSDAY, MAY 19

Morning Session

The Orthopaedic Treatment of Tuberculosis of the Spine in a Military Tuberculosis Center
Lieutenant Colonel Harold S McBurney, Denver, Colorado (by invitation)
Fusion of the Shoulder Joint in Children, Utilizing Autogenous Bone Graft
Charles R Rountree, M D, Oklahoma City, Oklahoma
Conclusions Concerning the Use of Refrigerated Bone in Orthopaedic Surgery
Philip D Wilson, M D, New York, N Y
Treatment of Sclerotic or Aseptic Non-Union of the Tibia with an Associated Intact or Healed Fibula
Carl E Badgley, M D, Ann Arbor, Michigan
Correlation of Myelographic and Operative Findings in Intervertebral-Disc Lesions
J Albert Key, M D, St Louis, Missouri
Cauda Equina Tumors as a Cause of the Low-Back Sciatic Syndrome
James W Toumey, M D, Boston, Massachusetts

FRIDAY, MAY 20

Morning Session

Restriction of Growth of Bone by Pins through the Epiphyseal Cartilage Plate
Sylvan L Haas, M D, San Francisco, California
Acute Non-Tuberculous Psoas Abscess
Isadore Zadek, M D, New York, N Y
Giant-Cell Tumors in Children
Harold D Palmer, M D, Denver, Colorado (by invitation)
Factors which Influence Survival in Bone Sarcoma
C Howard Hatcher, M D, Chicago, Illinois
The Effects of Radio Activity on Bone
John Z Bowers, M D, Washington, D C (by invitation)
Presidential Address
Ralph K Ghormley, M D, Rochester, Minnesota

SATURDAY, MAY 21

Morning Session

Congenital Metatarsus Varus
J Hiram Kite, M D, Atlanta, Georgia
A Study of a Large Series of Keller Operations Performed for Hallux Valgus
Mather Cleveland, M D, New York, N Y
Ski Injuries—Trauma of Lower Extremities Resulting from Torsion Strain
John R Moritz, M D, Sun Valley, Idaho (by invitation)
Chondromalacia of the Patella Early Manifestations and Late Results, Diagnosis, and Treatment
Edwin F Cave, M D, Boston, Massachusetts
Circulatory Changes in the Extremities, Associated with Infantile Paralysis and the Relation to the Occurrence of Shortening
William T Green, M D, Boston, Massachusetts

Noon Final Executive Session

By invitation of **The British Orthopaedic Association**, a group of orthopaedic surgeons, chosen by The American Orthopaedic Association, are visiting orthopaedic centers in England and Scotland.

The group, representing ten different sections of the country, are:

Lee Ramsay Straub, M.D., New York, N.Y.,
Carroll B. Larson, M.D., Boston, Massachusetts,
John Hamilton Allan, M.D., Philadelphia, Pennsylvania,
Hugh Smith, M.D., Memphis, Tennessee,
S. Benjamin Fowler, M.D., Nashville, Tennessee,
Benjamin E. Obletz, M.D., Buffalo, New York,
John J. Fahey, M.D., Chicago, Illinois,
William H. Bickel, M.D., Rochester, Minnesota,
Verne T. Inman, M.D., San Francisco, California,
Donald W. Blanche, M.D., Los Angeles, California.

With a similar group from The Canadian Orthopaedic Association, these men gathered in New York on March 16 for a Clinical Day arranged at some of the New York hospitals, followed by a farewell dinner given at the Harvard Club in New York.

They sailed on March 17 and, after a week in London, will visit various other orthopaedic centers. They will attend the Spring Meeting of The British Orthopaedic Association, to be held in Nottingham the last of April under the presidency of Mr. S. Alan S. Malkin. They will return before the Annual Meeting of The American Orthopaedic Association, to be held in Colorado Springs May 18 through 21.

This unusual opportunity has been made available to these men through the generosity of The British Orthopaedic Association.

The Executive Board of the **American Public Health Association** announces that the Seventy-seventh Annual Meeting of the Association and meetings of related organizations will take place in New York City, October 24 to 28. The Hotels Statler and New Yorker are joint headquarters.

The Alumni of the **Hospital for Joint Diseases**, New York City, will conduct an Orthopaedic Conference from May 12 through May 14. On the evening of May 12, Dr. C. Howard Hatcher of Chicago will deliver the Sir Robert Jones Lecture at the Hospital on "The Results of Treatment of Bone Sarcoma". All those interested are invited to attend.

The Sixty-first Annual Meeting of the **American Association of Railway Surgeons** will be held at the Drake Hotel, Chicago, on June 30, July 1, and the morning of July 2, 1949.

Dr. M. N. Smith-Petersen of Boston has recently been honored by election to honorary membership in the Royal Medical Society of Edinburgh.

Dr. Donald E. King has been appointed Professor of Bone and Joint Surgery at Stanford University.

The **National Society for Crippled Children and Adults, Inc.**, has recently conducted the annual sale of Easter seals for the support of its work.

Recently this Society, through its Executive Director, Lawrence J. Linck, awarded eight scholarships to physicians, surgeons, and physical therapists for specialized training in cerebral palsy. The scholarships were made possible by Alpha Chi Omega, national women's sorority. They cover study at the Children's Rehabilitation Institute, Cockeysville, Maryland, under the supervision of Dr. Winthrop M. Phelps, President of the American Academy for Cerebral Palsy.

The **Sociedad Mexicana de Ortopedia**, founded in 1944, announces the election of the following officers for 1949: Luis García Figueroa, M.D., President; J. J. Domínguez, M.D., Treasurer; and Ladislao Solares, M.D., Secretary.

Dr. Arthur Steindler of Iowa City and Dr. Guy A. Caldwell of New Orleans have been made honorary members of this organization.

The **American Board for Certification of the Prosthetic and Orthopaedic Appliance Industry, Inc.**, has been established, with headquarters in Washington, D. C. The purpose of the Board is to improve professional standards of manufacturers of artificial limbs and braces.

Three orthopaedic surgeons and four leaders in the orthopaedic-appliance industry constitute the group which will grant certification. The orthopaedic surgeons are Dr. Rufus Alldredge, New Orleans, Louisiana; Dr. Henry H. Kessler, Newark, New Jersey; and Dr. Atha Thomas, Denver, Colorado. Lay members are Chester C. Haddan, Denver, Colorado; Lee J. Fawver, Kansas City, Missouri; J. B. Korrady, Chicago, Illinois; and David E. Stolpe, New York, N. Y. Mr. Haddan is President and Glenn E. Jackson, Washington, D. C., is Executive Director.

An agreement of affiliation between the **New York Hospital** and the **Hospital for Special Surgery** has been announced jointly by William H. Jackson, President of the Society of the New York Hospital, and Samuel S. Duryee, President of the New York Society for the Relief of the Ruptured and Crippled. This affiliation, which has the approval of the Hospital Council of Greater New York and is subject to the approval of the Court, calls for the erection by the New York Society for the Relief of the Ruptured and Crippled of a new hospital of approximately 170 beds for orthopaedic and arthritic patients on land on the East River Drive between 70th and 71st Streets. This land, which is now owned by the New York Hospital, will be transferred by it without monetary consideration to the Hospital for Special Surgery.

Although the hospitals will continue as independent corporations, meeting their own operating costs and expenses, each will avail itself of the experience and facilities of the other. General surgery and internal medicine (other than treatment of arthritis) will be conducted in the New York Hospital, and orthopaedic surgery and treatment of arthritis, in the Hospital for Special Surgery. Upon the opening of the new hospital, Dr. Philip D. Wilson, the present Surgeon-in-Chief of the Hospital for Special Surgery, will assume the title of Director of Orthopaedic Surgery. Dr. Frank Glenn is the Surgeon-in-Chief of the New York Hospital and the Professor of Surgery of Cornell University Medical College.

This affiliation brings close together two of the oldest and best known of New York's hospitals. The Society of the New York Hospital, created by royal charter dated June 13, 1771, has maintained a general hospital for 178 years. It was the city's first hospital, originally located on Broadway near Duane and Worth Streets. In 1927, the agreement with Cornell University brought about the creation of the present New York Hospital–Cornell Medical Center on York Avenue at East 68th Street.

The New York Society for the Relief of the Ruptured and Crippled has maintained a hospital in New York City since 1863. For years, the old Hospital for the Ruptured and Crippled was on the site now occupied by the Hotel Commodore. Its present Hospital for Special Surgery is on East 42nd Street between First and Second Avenues, and its services and facilities pertain particularly to the care and treatment of patients afflicted with crippling conditions and deformities of an orthopaedic nature, arthritis, and hernia. Programs of teaching and research are also conducted.

THE AMERICAN ACADEMY OF ORTHOPAEDIC SURGEONS

The Sixteenth Annual Convention of The American Academy of Orthopaedic Surgeons was held at the Palmer House, Chicago, January 22 to 27, 1949, under the presidency of Dr. Myron O. Henry. Total registration at the meeting was 1,975. The Audio-Visual Program and Instructional Courses, under the chairmanship of Dr. Charles N. Pease, were well attended.

On Monday afternoon the new members were presented with their diplomas, following which Dr. Henry gave his Presidential Address. The remainder of the afternoon was devoted to the first Executive Session. A roster of the new members is as follows:

Seymour M. Albert, M.D., Philadelphia, Pennsylvania
Harold Altman, M.D., New York, N. Y.
Moss M. Bannerman, M.D., Baton Rouge, Louisiana
Robert John Bannow, M.D., Pontiac, Michigan
Jurgens H. Bauer, M.D., Syracuse, New York

Thomas Beath, M D , Richmond, Virginia
Charles O Bechtol, M D , Oakland, California
Roderick E Begg, M D , Portland, Oregon
George D B Berkett, M D , New Orleans, Louisiana
George A Berkheimer, M D , Harrisburg, Pennsylvania
Emanuel Blumenfield, M D , New York, N Y
Gwernydd Newton Boice, M D , McKeesport, Pennsylvania
Francis N Brill, M D , Springfield, Illinois
Joseph Edmund Brown, M D , Cleveland, Ohio
Robert Clifton Brown, M D , Neenah, Wisconsin
Everett I Bugg, Jr , M D , Durham, North Carolina
Ernest M Burgess, M D , Seattle, Washington
Reynoldson Duke Butterworth, M D , Richmond, Virginia
Irvin Cahen, M D , New Orleans, Louisiana
Peter Louis Carnesale, M D , Milwaukee, Wisconsin
Carl G Caspers, M D , Minneapolis, Minnesota
Harold M Childress, M D , Jamestown, New York
Kenneth Christophe, M D , Brookline, Massachusetts
Roy C Ciccone, M D , Bloomfield, New Jersey
Beverley Boyden Clary, M D , Richmond, Virginia
Paul J Collopy, M D , Milwaukee, Wisconsin
Kenneth L Cooley, M D , Rochester, New York
Frederick C Courten, M D , Richmond Hill, New York
Robert R Crawford, M D , Mansfield, Ohio
John J Cushner, M D , York, Pennsylvania
A J Day, M D , Detroit, Michigan
Allan Montague Ferry, M D , Washington, D C
David Leonard Filtzer, M D , Baltimore, Maryland
Samuel Emory Flook, M D , Dayton, Ohio
William Porter Forcade, M D , San Francisco, California
Dale E Fox, M D , Cincinnati, Ohio
Clarence LeRoy Francisco, M D , Kansas City, Kansas
Russell Victor Fuldner, M D , New Haven, Connecticut
Maurice Gershman, M D , Far Rockaway, New York
Arthur L Glassman, M D , Houston, Texas
C Fred Goeringer, M D , Philadelphia, Pennsylvania
James Thomas Green, Jr , M D , Columbia, South Carolina
Edward D Hagerty, M D , Manchester, New Hampshire
Harold T Hansen, M D , South Orange, New Jersey
Kenneth J Harmon, M D , Niagara Falls, New York
Joel Hartley, M D , New York, N Y
Henry Monroe Hills, Jr , M D , Charleston, West Virginia
William Vincent Hindle, M D , Providence, Rhode Island
Edward Charles Holscher, M D , St Louis, Missouri
Carl E Horn, M D , Sacramento, California
William Templeton Howard, M D , Memphis, Tennessee
Denman Carter Hucherson, M D , Houston, Texas
John T Jacobs, M D , Denver, Colorado
Floyd H Jergesen, M D , San Francisco, California
Herman Joffe, M D , Chicago, Illinois
Orville Noble Jones, M D , Portland, Oregon
Elias Noah Kaiser, M D , Montgomery, Alabama
Robert Patton Kelly, Jr , M D , Emory University, Georgia
Richard Hotchkiss Kiene, M D , Kansas City, Missouri
David J King, M D , Wilmington, Delaware
Barnard Kleiger, M D , New York, N Y
Marvin Pierce Knight, M D , Dallas, Texas
Harold H Kuhn, M D , Charleston, West Virginia
Kenton D Leatherman, M D , Louisville, Kentucky
Harry Linwood Leavitt, M D , Seattle, Washington
Samuel Levine, M D , Lynn, Massachusetts
John Lyford, III, M D , Louisville, Kentucky
James M McBride, M D , Lima, Ohio

John O'D McCabe, M D , Milwaukee, Wisconsin
Richard M Mellen, M D , Colorado Springs, Colorado
Donald Irwin Minnig, M D , Akron, Ohio
Edwin Leslie Mollin, M D , Akron, Ohio
Donald E Moore, M D , Eugene, Oregon
Joseph Mahon Moore, M D , Vicksburg, Mississippi
Robert Dunham Moore, M D , Chicago, Illinois
Donald M Norquist, M D , Pasadena, California
Leon Ocel Parker, M D , San Francisco, California
Paul A Pemberton, M D , Salt Lake City, Utah
Homer C Pheasant, M D , Los Angeles, California
Anthony J Pisani, M D , New York, N Y
David Poverman, M D , New Haven, Connecticut
Willis Law Pugh, M D , Evansville, Indiana
Irving Redler, M D , New Orleans, Louisiana
Joseph M Regan, M D , Milwaukee, Wisconsin
John Gilbert Reid, M D , Detroit, Michigan
J Antonio Samson, M D , Montreal, Canada
Walter William Schwartz, M D , Chicago, Illinois
John R Schwartzmann, M D , Tucson, Arizona
William Bostwick Sheppard, M D , Oakland, California
Mary Stults Sherman, M D , Chicago, Illinois
Stewart W Shimonek, M D , St Paul, Minnesota
Carroll Mitchell Silver, M D , Providence, Rhode Island
Lyman Smith, M D , Elgin, Illinois
Donald Ellsworth Starr, M D , Vancouver, Canada
Richard Carl Stauffer, M D , Fort Wayne, Indiana
Raymond Oscar Stein, M D , Philadelphia, Pennsylvania
Marcus Jefferson Stewart, M D , Memphis, Tennessee
Thomas D Thompson, M D , Spokane, Washington
Arthur Stanley Thurm, M D , Trenton, New Jersey
Eulyss Robert Troxler, M D , Greensboro, North Carolina
Frank G Vieira, M D , Stockton, California
Chester W Waters, M D , Omaha, Nebraska
Melvin Brent Watkins, M D , New York, N Y
Heins Wichman, M D , Jersey City, New Jersey
Paul G Wiesenfeld, M D , Perth Amboy, New Jersey
Milton Jay Wilder, M D , Baltimore, Maryland
Charles H Wilson, M D , Birmingham, Alabama
John Curtis Wolgamot, M D , Great Falls, Montana
William V Woods, M D , Indianapolis, Indiana
Robert Montimer Wray, M D , Cedar Rapids, Iowa
Peter B Wright, M D , Augusta, Georgia

Elected to Honorary Membership was
Albert B Ferguson, M D , Boston, Massachusetts

The scientific program was held on Tuesday, Wednesday, and Thursday

TUESDAY, JANUARY 25

Morning Session

Progressive-Resistance Exercises in Orthopaedics
Thomas L DeLorme, M D , Boston, Massachusetts (by invitation)
Discussion Philip Lewin, M D , Chicago, Illinois,
Francis E West, M D , San Diego, California

Electromyography in Orthopaedics
Arthur L Watkins, M D , Boston, Massachusetts (by invitation)
Discussion Joseph E Markee, M D , Durham, North Carolina (by invitation),
R Plato Schwartz, M D , Rochester, New York

The Circulation in Foetal and Infant Spines and Its Probable Influence on Spinal Degeneration
W Roland Ferguson, M D , Baltimore, Maryland (by invitation)
Discussion Joseph S Barr, M D , Boston, Massachusetts,
J Albert Key, M D , St Louis, Missouri

Pott's Paraplegia
George J Garceau, M D , and Thomas Brady, M D (by invitation), Indianapolis, Indiana
Discussion Mather Cleveland, M D , New York, N Y ,
J Hiram Kite, M D , Atlanta, Georgia
Streptomycin in Tuberculous Bone and Joint Lesions Complicated with Mixed Infection and Sinuses
David M Bosworth, M D , Alfonso Della Pietra, M D (by invitation), and Richard Farrell, M D (by invitation), New York, N Y
Discussion Frederick L Liebolt, M D , New York, N Y ,
John R Norcross, M D , Chicago, Illinois

Afternoon Session

The Influence of the Contact Compression Factor on the Osteogenesis of Surgical Fractures
G W N Eggers, M D , Thomas Shindler, M D (by invitation), and Charles M Pomerat, Ph D (by invitation), Galveston, Texas
Discussion Hugh Smith, M D , Memphis, Tennessee,
Edward L Compere, M D , Chicago, Illinois
The Relation of Atomic Energy to Clinical Medicine
John Z Bowers, M D , Washington, D C (by invitation)
Stabilizing Operations on the Foot—A Study of the Indications, Techniques Used, and End Results
Robert L Patterson, Jr , M D , Frank F Parrish, M D (by invitation), and Elwood N Hathaway, M D (by invitation), New York, N Y
Progressive Muscular Atrophy of the Peroneal Type (Charcot-Marie-Tooth) Orthopaedic Management and End-Result Study
Julian E Jacobs, M D , Charlotte, North Carolina, and Commander Chalmers Carr, M C Oakland, California (by invitation)
Discussion W M Roberts, M D , Gastonia, North Carolina

WEDNESDAY, JANUARY 26

Morning Session

A Clinical Evaluation of the Merthiolate Bone Bank A Preliminary Report
Fred C Reynolds, M D , and David Oliver, M D (by invitation), St Louis, Missouri
Experiences in the Use of Homogenous (Bone Bank) Bone
James B Weaver, M D , Kansas City, Kansas
Discussion Alberto Inclan, M D , Havana, Cuba,
P D Wilson, M D , New York, N Y
Andry and the Orthopaedia
R Beverly Raney, M D , Durham, North Carolina
Fixed Osteotomy in the Treatment of Non-Unions of the Neck of the Femur
John H Moe, M D , and Harry B Hall, M D , Minneapolis, Minnesota
Discussion James A Dickson, M D , Cleveland, Ohio,
Henry Milch, M D , New York, N Y
End-Result Study of Arthrodesis of the Hip Joint
Frank E Stinchfield, M D , and William U Cavallaro, M D (by invitation), New York, N Y
Discussion M N Smith-Petersen, M D , Boston, Massachusetts,
Rudolph S Reich, M D , Cleveland, Ohio

Afternoon Session

Prediction of Unequal Growth in the Lower Extremities in Anterior Poliomyelitis
Allan J Stinchfield, M D (by invitation), J A Reidy, M D , and Joseph S Barr, M D , Boston, Massachusetts
Controlled Bone Growth by Epiphyseal Stapling Preliminary Report
Walter P Blount, M D , and George R Clarke, M D (by invitation), Milwaukee, Wisconsin
Discussion William T Green, M D , Boston, Massachusetts,
J Warren White, M D , Greenville, South Carolina
The Mechanism of the Structural Changes in Scoliosis
Alvin M Arkin, M D , New York, N Y
Discussion Henry F Ullrich, M D , Baltimore, Maryland,
Joseph C Risser, M D , Pasadena, California
The Mechanism of Endosteal New-Bone Formation in Estrogen-Treated Mice
Marshall R Urist, M D (by invitation), Ann Marie Budy, B S (by invitation), and Franklin C McLean, M D (by invitation), Chicago, Illinois
Discussion A R Shands, Jr , M D , Wilmington, Delaware,
Robert W Johnson, M D , Baltimore, Maryland

THURSDAY, JANUARY 27

Morning Session

Causes for Amputations Performed at Walter Reed General Hospital in Years 1947 and 1948

Lieutenant Colonel Lloyd W Taylor, M C (by invitation), and Colonel August W Spittler, M C (by invitation), Washington, D C

Discussion Rufus H Alldredge, M D, New Orleans, Louisiana,
Francis M McKeever, M D, Los Angeles, California,
Mather Cleveland, M D, New York, N Y

Fractures of Both Bones of the Forearm in Adults

Robert A Knight, M D, and George D Purvis, M D (by invitation), Memphis, Tennessee

Discussion Walter G Stuck, M D, San Antonio, Texas,
D B Slocum, M D, Eugene, Oregon

Transplantation of the External Oblique Muscle for Abductor Paralysis

Lowell Thomas, M D, Indianapolis, Indiana (by invitation), T Campbell Thompson, M D, New York, N Y, and L Ramsay Straub, M D, New York, N Y

Discussion Frank D Dickson, M D, Kansas City, Missouri,
Leo Mayer, M D, New York, N Y

Pseudarthrosis Following Operation for Spinal Fusion

Edgar L Ralston, M D, Philadelphia, Pennsylvania (by invitation), Walter A L Thompson, M D, New York, N Y (by invitation), and Alan D Smith, M D, New York, N Y

Discussion Joseph A Freiberg, M D, Cincinnati, Ohio,
Fremont A Chandler, M D, Chicago, Illinois

At the Instructional Course dinner on Saturday night, an "Information Please" program was presented, which was both instructive and entertaining

The Annual Dinner was held on Wednesday evening After appropriate introduction by President Henry of the men seated at the head table, a short, informal talk was given by Mr H A Brittain

The second Executive Session was held at 12 30 P M on Thursday, at which time the awards listed herewith were announced The presidential medallion was presented to Dr Myron O Henry by the past President, Dr Rex L Diveley The gavel was presented to the new President, Dr Mather Cleveland, by the retiring President, Dr Henry Following a short acceptance speech by Dr Cleveland, the meeting was adjourned

The following awards were made by the Committee on Scientific Investigation

Class I Originality in Research Problems

Award William Cooper, M D, New York Hospital for Special Surgery, "Aseptic Necrosis of the Femoral Head in Adults"

Honorable Mention Henry W Meyerding, M D, Mayo Clinic, Rochester, Minnesota, "Benign and Malignant Giant-Cell Tumors of Bone"

Honorable Mention Carl E Badgley, M D, University of Michigan School of Medicine, Ann Arbor, "Ehlers-Danlos Syndrome"

Class II Scientific Importance and Information

Award G W N Eggers, M D, and T O Shindler, M D, University of Texas School of Medicine, Galveston, "The Influence of the Contact Compression Factor on the Osteogenesis of Surgical Fractures"

Honorable Mention Robert Lee Patterson, Jr, M D, Frank F Parrish, M D, and Elwood N Hathaway, M D, New York Hospital for Special Surgery, "Stabilization Operations on the Foot"

Honorable Mention Irvin Stein, M D, and Raymond O Stein, M D, Philadelphia, Pennsylvania, "Chemistry of Bone Lesions"

Class III Clinical Value

Award Walter P Blount, M D, Donald W McCormick, M D, and George Clarke, M D, Milwaukee Children's Hospital, Milwaukee, Wisconsin, "Temporary Arrest of Longitudinal Bone Growth by Epiphyseal Stapling"

Honorable Mention David M Bosworth, M D, Alfonso Della Pietra, M D, and Richard Farrell, M D, New York, N Y, "Streptomycin in the Treatment of Joint Tuberculosis with Mixed Infection"

Honorable Mention Fred C Reynolds, M D, and David R Oliver, M D, Washington University School of Medicine, St Louis, Missouri, "Merthiolate Bone Bank"

The following awards were made by the Committee on Audio-Visual Education

Gold Medal Herbert N Coleman, M D, Toronto, Canada, "Surgery of the Knee Joint"

Certificate of Merit Armin Klein, M D, Robert J Joplin, M D, John A Reidy, M D, and Joseph Hanelin, M D, Boston, Massachusetts, "Slipped Capital Femoral Epiphysis"

Certificate of Merit David M Bosworth, M D, Richard Farrell, M D, and Alfonso Della Pietra, M D, New York, N Y, "Tuberculosis of Joints Following Use of Streptomycin"
Honorable Mention Lyon K Loomis, M D, New Orleans, Louisiana, "Stenosing Tenosynovitis at Radial Styloid Process"
Honorable Mention Benjamin Fowler, M D, Nashville, Tennessee, "Intramedullary Fixation of the Femur"

The following awards were made by the Committee on Gadgets
Duncan C McKeever, M D, Houston, Texas, "Disposable Towel Clips"
Donald B Slocum, M D, and Donald E Moore, M D, Eugene, Oregon, "A Method of Back Strapping"
Hugh T Jones, M D, Los Angeles, California, "Pedangle Back Rest"

The Seventeenth Annual Convention will be held at the Waldorf-Astoria, New York City, February 11 to 16, 1950, under the presidency of Dr Mather Cleveland

COMPTON RIELY

1872–1948

Dr Compton Riely of Baltimore died in Martinsburg, West Virginia, on July 27, 1948, at the age of seventy-six Born in Summit Point, West Virginia, he received his medical education at the University of Maryland, where he was graduated in 1897 For many years he was connected with the division of orthopaedic surgery at his alma mater and held the rank of clinical professor

In addition, he was certified as a specialist by The American Board of Orthopaedic Surgery, was a fellow of the American Medical Association, and a member of The American Orthopaedic Association He was affiliated with the Cambridge-Maryland Hospital and the University and Franklin Square Hospitals of Baltimore He was also attending surgeon on the staff of the King's Daughters' Hospital in Martinsburg

The death of Dr Riely marks the passing of one of a group of surgeons, of whom only a few remain, who helped bridge the gap between the older conservatism and the brilliant surgical aggressiveness of modern orthopaedic treatment He brought the benefits of his specialty to the remoter parts of Maryland and West Virginia, years before the introduction of more elaborate and systematic care of the crippled, first by voluntary organizations, later by state and federal agencies He was a determined individualist and often it was difficult to convince him that methods other than his own had merit In the main, he employed non-operative means whenever possible and relied to a great extent upon splints, braces, and casts In the field of immobilization he was adept A cast was applied with meticulous and time-consuming care, but finally there emerged an efficient and handsome support He had great confidence in the healing power of prolonged rest, convinced that nature, if given ample opportunity, wrought the desired result His methods doubtless brought comfort and relief to many who came under his care

ARTHUR G DAVIS

1887–1949

On February 20, 1949, Arthur G Davis died, at a time when he was at the height of his professional career and was actively engaged in conducting a large private practice and in caring for the crippled poor in his community With his passing, orthopaedic surgery has lost one of its most energetic and original thinkers and northwestern Pennsylvania has lost the man who pioneered in the development of orthopaedic surgery in that region and continued to work untiringly in this field

Arthur Davis was born in Sebring, Ontario, in 1887, and his family moved to Buffalo in 1896 He was educated at the University of Buffalo, receiving his bachelor's degree in 1907 and his doctorate of medicine in 1913 He became interested in orthopaedic surgery while serving in the United States Army during the First World War After his discharge from the Army, he spent eighteen months in Boston at the Massachusetts General and Children's Hospitals, furthering his training in this specialty He then began the practice of orthopaedic surgery in Erie, Pennsylvania, and, by industry and ability, rapidly established himself as a leader in the community, both as a surgeon and as a citizen

Relatively soon after beginning practice, Dr Davis became interested in compression fractures of the spine In spite of his remoteness from a suitable laboratory, he studied anatomical material and determined that, in these injuries, the anterior longitudinal ligament remains intact and is an unusually strong structure He then reasoned that the deformity in compression fractures of the spine could be corrected with safety by gently manipulating the spine in hyperextension A method embodying the principles of manipulation, combined with traction, was devised and applied to patients with compression fractures of the spine The results were surprisingly good, and a description of the method and of cases illustrating the results obtained by its use was submitted to The American Orthopaedic Association as a thesis in 1928 The work * was accepted immediately and has revolutionized our treatment of these fractures

Also in the 1920's, Dr Davis conducted experiments upon the irradiation of milk with ultraviolet light, in an effort to prevent rickets The completion of Steenbock's work on Vitamin D made this unnecessary He also contributed to our knowledge of the treatment of fractures, especially those of the leg, in which he used the fibula to aid repair of the tibia When the treatment of fractures by reduction machines and external skeletal fixation was receiving undue emphasis, Arthur Davis presented a series of cases in which union had been delayed or prevented by the distraction which is so easily obtained and maintained by this method, and offered a theoretical explanation of the mechanism by which the ill effects were produced Always a keen student of the surgery of trauma, he was one of the foremost exponents of the pressure dressing, combined with immobilization, in the treatment of compound fractures, and presented brilliant results in a series of cases treated by his method

Dr Davis was greatly interested in research and often spoke with envy of those whose lot was cast in an environment where opportunity to study and adequate laboratory facilities were available However, it is possible that, had such been his lot, the world would have been the poorer His forte was clinical research and the treatment of patients

His life might well be an inspiration to men who practise in localities remote from medical centers Under such circumstances, Dr Davis worked untiringly and enthusiastically for twenty-six years, and throughout this period he continued to contribute to our knowledge and remained an important figure in American orthopaedic surgery A dreamer of dreams, a poser of questions about the universe, and a good companion, he will long be missed by his community, his friends, and his wife and four children His work will live Truly, it may be said of him that "the greatest reward for hard work is the ability to do more and better work"

* Fractures of the Spine J Bone and Joint Surg , 11 133–156 (Jan) 1929

Book Reviews

PHYSIOLOGY OF MOTION DEMONSTRATED BY MEANS OF ELECTRICAL STIMULATION AND CLINICAL OBSERVATION AND APPLIED TO THE STUDY OF PARALYSIS AND DEFORMITIES Dr G B Duchenne Translated and Edited by Emanuel B Kaplan, M D Philadelphia, J B Lippincott Company, 1949

This book, which originally appeared in 1867, represented the results of more than twenty years of investigation on the physiology of motion in man The first idea of the author was to determine by electromuscular experimentation and clinical observation the proper actions which muscles produce, their mechanism, and the sources which contribute to the normal position of extremities during rest By localized faradization of individual muscles, he intended to confirm the observations of the older anatomists, who had devoted so much study to the anatomy and physiology of muscles

Duchenne's early experiments convinced him that this localized faradization was insufficient to give an accurate understanding of the physiology of voluntary motion He came to realize that clinical observations of the action of individual muscles in relation to others of the group, both in normal and abnormal conditions, were necessary in order to understand physiological synergy of muscles This led to the study of many patients with generalized and incomplete paralyses, special interest being in the patient with very limited paralysis

By such observations, Duchenne came to understand the function of the individual muscles and their relation to one another, also the compensation provided when even one was atrophied or paralyzed Without the exact knowledge of these facts, it was impossible to explain the mechanism of many deformities and distortions, and to determine the treatment indicated Convinced of the importance of his findings, Duchenne undertook the writing of his book as a contribution to the solution of this physiological problem

The first two parts of the book are devoted to the study of motion of the upper and lower extremities The third part explains the respiratory movements and movements of the craniovertebral column, with an appendix which discusses the relation of sight to voluntary motion A supplement, added at the request of the publisher, deals with motion of the face

Valuable as Duchenne's book is, it has not been generally read by surgeons of the English-speaking world, because its treasures were hidden in a difficult French style, and the old French nomenclature differs completely from the nomenclature adopted by modern English and American anatomists Dr Kaplan has rendered a great service to the profession in making available in English this valuable classic Few will appreciate the magnitude of his task, but, because of its accomplishment, many will be able to study Duchenne's investigations and conclusions The book will be of real value to the anatomist, the orthopaedic surgeon, the neurologist, and all who are interested in the problems of rehabilitation

The illustrations are line drawings reproduced from the original text Quite suitably, the type used in the book is a type face of French origin The book is beautifully printed and bound, a credit to the publishers who have undertaken this work

LA LUSSAZIONE CONGENITA DELL'ANCA NUOVI CRITERI DIAGNOSTICI E PROFILATTICO-CORRETTIVI Marino Ortolani, Bologna, Cappelli Editore, 1948 1,500 lire

The secret of success in the treatment of congenital dislocations of the hip is early diagnosis To this end, many different tests have been devised In the main, these tests are based upon roentgenographic criteria and disclose anatomical variations from the normal which are suggestive of a congenital dislocation Generally speaking, these tests cannot be depended upon during the first three months of extra-uterine life It is precisely during this period that what the author calls the "*segno dello scatto*"—which may be freely translated as the "jump" sign—is especially valuable and is, in fact, pathognomonic

The "jump" sign is elicited with the infant supine The lower extremities are fixed upon the pelvis and held in a position of slight adduction and internal rotation The extremities are then slowly abducted and externally rotated As the femoral head mounts the barrier of the glenoidal labrum, escaping from the acetabulum, a characteristic jump can be felt and sometimes heard This is similar to the manoeuvre which was formerly recommended as a test for the stability of closed reductions of congenital dislocations

The first portion of this excellent monograph is devoted to a careful study of the anatomical basis of the "jump" sign This is accomplished by careful arthrograms, roentgenograms, and anatomical dissection. The latter part of the work is given over to a description of the method of treatment by flexion and wide abduction, without immobilization in plaster

This is a valuable contribution and would well merit translation into the English language It is profusely illustrated with photographs of roentgenographic reproductions and anatomical dissections

RECENT ADVANCES IN SURGERY Ed 3 Harold C Edwards, C B E, M S, F R C S London, J and A Churchill, 21 shillings, Philadelphia, The Blakiston Company, 1948 $6 50

This volume, the first two editions of which were edited by Sir Heneage Ogilvie and published in 1928 and 1929, is an attempt to show current surgical practices to the returned war surgeon or his confrere who has been unable to keep up with contemporary surgical literature It is necessarily sketchy as regards detail, but the bibliography is adequate

It is divided into seven parts General, which includes wound healing, shock, burns, water balance, et cetera, the Alimentary Tract, which also deals with the pancreas and spleen, but not the gall bladder, the Blood Vessels, and the Ductless Glands All of these sections were written by the Editor A section on the Thorax, by R C Brock, discusses surgery of the heart and bronchial carcinoma D W C Northfield has contributed a section on the Nervous System which is rather more inclusive and detailed than the rest of the volume The final part is on Radiotherapy in Malignant Disease by Sir Stanford Cade, in this section the methods for treating each type of malignant disease are outlined

As the Editor states in the Preface, many subjects have been omitted and the reports on some had become outdated by the time the page proofs were read On the whole, however, this volume represents a reasonably complete survey of the developments in surgery during the past few years The writing is simple, clear, and eminently readable The authors' opinions are constantly expressed in controversial matters For the surgeon who has fallen behind in his reading of current surgical literature and for the physician who wants to know what new surgical procedures may benefit his patient, this volume will be of value

BACTERIAL AND MYCOTIC INFECTIONS OF MAN René J Dubos, Ph D, Editor Philadelphia, J B Lippincott Company, 1948 $5 00

In his Preface, Dr Dubos states that this book is intended to present "some knowledge of the bacteria, actinomycetes and molds pathogenic for man, as well as of the phenomena which characterize the infectious process" Included are the fundamentals of bacteriology,—the morphology and physiology of the bacteria and their pathogenic properties, as well as a discussion of immunity, allergy, and epidemiology

The book deals with those relationships of parasite and host which concern the infectious diseases The largest portion is devoted to a discussion of bacterial and mycotic groups The disease or diseases caused by a parasitic agent are considered, and their treatment is outlined Each chapter has been written by an authoritative worker in the field, and thus each subject is treated as an entity Although this method of presentation fails to correlate the various diseases one with another, it makes the book of more value for reference

An obvious lack in a book such as this would appear to be any mention of the virus or rickettsial diseases, but the omission was intentional These agents are being discussed in a separate volume

This work has been prepared from a practical rather than a theoretical point of view, and definite laboratory methods are set forth It was written primarily for medical students, but will have interest for the general practitioner, as he comes in contact with the problems of infection Each chapter contains a bibliography with references to recent publications by other workers The whole subject has been presented clearly and concisely, and represents a valuable contribution to the bacteriological literature

BRITISH SURGICAL PRACTICE Volume 3 Edited by Sir Ernest Rock Carling, F R C S, F R C P, and J Paterson Ross, M S, F R C S London, Butterworth and Company, Ltd, 60 shillings (25 pounds for the set), St Louis, C V Mosby Company, 1948 $15 00 ($125 00 for the set)

The third volume of *British Surgical Practice*, recently issued, is of special interest to *Journal* readers, because of the sections which happen to be included in this alphabetical division Most important of these is "Deformities", prepared by H Osmond-Clarke, F R C S, of the London Hospital The various types of congenital and acquired deformities are clearly and concisely presented, with the etiology, clinical picture, differential diagnosis, and treatment, most of them illustrated with excellent photographs, drawings, or roentgenograms

Other chapters of value to the orthopaedic surgeon are "Contractures", by L W Plewes, M D, Luton and Dunstable Hospital, "Cervical Rib and the Scalenus Syndrome", by Lambert Rogers, F R C S, Royal Infirmary, Cardiff, "Diseases of Epiphyses", by H E Harding, F R C S, Westminster Hospital, London, and "Chordoma", by Harvey Jackson, F R C S, St Thomas's Hospital, London

The present volume is additional evidence of the great value of this series to the surgeon

BRITISH SURGICAL PRACTICE Volume 4 Edited by Sir Ernest Rock Carling, F R C S, F R C P, and J Paterson Ross, M S, F R C S London, Butterworth and Company, Ltd, 60 shillings (25 pounds for the set), St Louis, C V Mosby Company, 1948 $15 00 ($125 00 for the set)

This book, another in the excellent series dealing with conditions usually treated by surgical techniques, follows the same plan as the earlier volumes, the material being classified under definition and etiology,

clinical picture, differential diagnosis, treatment, results, and prognosis Of special interest to *Journal* readers are the chapters on "Fascial Grafts", by W Edward Gallie, M D , of the University of Toronto, "Surgery of the Foot", by T T Stamm, F R C S , of Guy's Hospital, London, "Fractures, Dislocations, Fracture Dislocations and Allied Injuries", by F W Holdsworth, F R C S , of Sheffield, "Gunshot Wounds and Allied Injuries", by C G Rob, F R C S , of St Thomas's Hospital, London, "Hand", by J N Barron, F R C S Ed , of Park Prewett Hospital, Basingstoke, and "Facio-Maxillary Injuries and Deformities", by Rainsford Mowlem, F R C S , of Middlesex Hospital, London, and Hill End Hospital, St Albans, and B W Fickling, F R C S , of Hill End Hospital, St Albans

The series is a valuable one, the material carefully prepared, well illustrated, and attractively presented

Campbell's Operative Orthopedics Ed 2 Edited by J S Speed, M D , and Hugh Smith, M D St Louis, C V Mosby Company, 1949 $30 00

In the first edition of "Operative Orthopedics", prepared in 1939 by Willis C Campbell and his associates, the purpose was to present to the experienced orthopaedic surgeon the various procedures which might be used in treating a given condition the operation of choice was usually indicated and the reasons therefor

The second edition of this work has been prepared primarily for a somewhat different reader,—the less experienced surgeon, well educated in the principles of orthopaedic surgery, but less able to make the wise decision as to the procedure indicated in the individual case For the convenience of this audience, preliminary data have been added, which Dr Campbell would have considered already well understood by the colleagues whom he had in mind as he outlined the material for his book Because of this different point of view, much of the text of the original edition has been omitted and a great deal of new material added

The development of new techniques in the last ten years has called for the inclusion of much new material, offering a wider choice of procedure for the surgeon Careful attention has been given to the preliminary data necessary for the understanding of the use of the various procedures, as well as to postoperative care, so important for the maximum benefit from a given operation

In the presentation of this new material, many new illustrations have been used, taken largely from the journals in which the various operations or refinements have been first presented by the individual surgeons, to whom credit is given

Three new chapters have been added "Preoperative and Postoperative Care", "Amputations", written by Dr Donald B Slocum, formerly associated with Dr Campbell, and "Peripheral Nerve Injuries", written by Dr Francis Murphey, Associate Director of Neurosurgery at the University of Tennessee A new section on "Rupture of Lumbar Discs", also written by Dr Murphey, has been added to the chapter on "Miscellaneous Affections of Joints" The new section, "Mold Arthroplasty of the Hip", added to the chapter on "Arthroplasty", was written by Dr M N Smith-Petersen of the Massachusetts General Hospital Dr R A Knight, who wrote the chapter on "Miscellaneous Affections of the Nervous System", was associated with Dr Winthrop M Phelps for one year and acknowledges his help in this field, Dr Phelp reviewed the section on "Cerebral Palsy"

All of the other authors who have contributed to this extensive work are members of the staff of the Campbell Clinic Dr Speed and Dr Smith, the Editors, collaborated with Dr Campbell in the preparation of the first edition Certainly Dr Campbell's associates have honored him in compiling this more complete edition of "Operative Orthopedics"

The first edition has been recognized as an invaluable reference book for all working in the field of orthopaedic surgery, the new edition will be of even greater value to the younger and less experienced operator The Editors and the publishers may well be proud of this contribution to orthopaedic literature

Plaster of Paris Technic Ed 2 Edwin O Geckeler, M D Baltimore, The Williams and Wilkins Company, 1948 $3 00

It is an art to use plaster-of-Paris skillfully Like other arts, perfection comes only through practice, directed along correct lines In this little volume the author has stressed the accepted method, not only by text, but by carefully chosen illustrations The incorrect method, in certain instances, is depicted by the resulting glaring mistakes

Plaster fixation for various conditions involving any part of the body is considered in a systematic anatomical fashion, starting with the occiput and proceeding by way of the vertebral column to each extremity Two chapters are devoted to plaster technique in war surgery The author has included a chapter on "Follow-up Care" which goes beyond the actual use of plaster-of-Paris

This monograph might well be a part of the plaster-room equipment

The Medical Annual A Year Book of Treatment and Practitioner's Index Editors Sir Henry Tidy, K B E , M A , M D (Oxon), F R C P , and A Rendle Short, M D , B S , B Sc , F R C S Bristol, England, John Wright and Sons, Ltd , 1948

The *Medical Annual* for 1948 represents the sixty-sixth year of publication of this compilation of the

current developments in medicine and surgery in Great Britain The format is essentially unchanged, brief discussions are included of medical topics, arranged alphabetically, followed by lists of recent pharmaceutical preparations and appliances, and of British and American books published during the year

Little in the most recent issue pertains directly to orthopaedic surgery, but an interesting discussion of epiphyseal disorders, including dysplasia epiphysialis multiplex and premature cessation of epiphyseal growth about the knee joint, is presented by T P McMurray, Emeritus Professor of Orthopaedic Surgery of the University of Liverpool Mr McMurray also deals with the relation of the pyriformis syndrome to sciatic pain "The term pyriformis syndrome is applied to that type of sciatica which is due to abnormal conditions of the pyriformis muscle, which are invariably traumatic in origin"

The subject matter of the *Annual* is comprehensive and, with its excellent index, the book is especially useful for reference

Textbook of Chiropody Margaret J McKenzie Swanson, B Litt, F Ch S Edinburgh, E and S Livingstone, Ltd, 20 shillings, Baltimore, The Williams and Wilkins Company, 1948 $5 00

This is a short treatise, written primarily for students of chiropody, still, it contains many practical aids which may be of value to anyone interested in foot problems The book includes definitions of pathological foot conditions, exceptionally well illustrated, followed by a description of the type of treatment a chiropodist is equipped to give

The author is to be congratulated on giving us a well-written, concise monograph on the diagnosis and treatment of foot ailments

Fractures and Dislocations for Practitioners Ed 4 Edwin O Geckeler, M D Baltimore, The Williams and Wilkins Company, 1948 $5 00

The worth of a book which has warranted four editions in less than eleven years is almost self-evident The latest edition of Dr Geckeler's text contains no extensive changes over the preceding edition, but recent developments in traumatic surgery, many of them the result of experience gained in World War II, are included About twenty illustrations have been added

The subject matter is presented simply and concisely, and the text is well illustrated Discussion of both immediate and follow-up treatment is included The author states "Emphasis has been placed on fundamentals for the student, and only the most practical methods have been selected for guidance of the practitioner" As a dependable, common-sense guide to present-day methods of treating fractures and dislocations, this book has proved of value

Polio and Its Problems Roland H Berg Philadelphia, J B Lippincott Company, 1948 $3 00

Mr Berg has traced the experimental work which has been done on poliomyelitis during the present century, with comments on some of the larger epidemics of the disease Particular mention is made of the contributing role of the National Foundation for Infantile Paralysis An interesting discussion of the Kenny method is presented, with the statement that the percentages of mortality and of residual paralysis following the Kenny treatment closely approximate those observed by physicians using other methods

The book is obviously written for the layman rather than the scientific worker

Collateral Circulation (Anatomical Aspects) Daniel P Quiring, Ph D Philadelphia, Lea and Febiger, 1949 $5 00

This small book describes the chief arterial and venous collateral channels of the body The author states "The term 'collateral circulation' denotes the subsidiary vascular channels, everywhere present in the circulatory network, which are a secondary line of defense against vascular breakdown These channels transport the blood with varying degrees of effectiveness when the main channels become occluded or interrupted" The factors which are considered as determining the establishment of collateral circulation are outlined, and are fundamentally those set forth in 1924 by Spalteholz

Much of the description is given by means of diagrams, many of them based on original dissections After a brief discussion of the formation of capillary, arterial, and venous channels, the collateral circulation for the head and neck, trunk, heart, and extremities is considered

Dr Quiring, who is head of the Anatomy Division at the Cleveland Clinic Foundation, has not attempted to discuss fully such a broad subject He has, however, provided a useful reference book, those who wish more specific information on circulatory problems may find his bibliography of value

ACKNOWLEDGMENTS

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American Volume

SPECIALIZATION IN MEDICINE WHAT IS ORTHOPAEDIC SURGERY?*

BY RALPH K. GHORMLEY, M D, ROCHESTER, MINNESOTA

As long as the practice of medicine was an art without much background of scientific knowledge, there was little or no need for specialization The physician with his imposing presence might control the situation, however serious it seemed With the advancement of knowledge due to the accumulation of scientifically proved facts, the need for specialization has arisen, and specialization in medicine and surgery has developed widely in this country and in most of the world where modern medical methods are in use

Specialization has developed because scientific discovery has wiped out many of the old concepts of illness and disease, and has made an accurate scientific knowledge of both diagnosis and treatment necessary to modern practice The many fields of specialization in medicine are developing so rapidly that one individual cannot possibly keep up to date on all of the scientific facts available Indeed, in some instances it is difficult for a specialist to keep up with all of the newer developments in his own field

In attempting to come to any conclusion regarding the scope of orthopaedic surgery, one must consider its past progress, its present position, and its possible future development

From time to time, many efforts have been made to define orthopaedic surgery A review of the presidential addresses of the past Presidents of this Association shows that many of them were thinking about this, and in some instances they went so far as to attempt to define or outline the scope of our specialty One must recognize the impact on our specialty of the developments in the entire field of medicine and surgery, for these have influenced its growth in many ways

As each specialty develops some new phase of knowledge, new challenges to the old order arise As long as we are free to advance that knowledge without the stifling influence of political control, new ideas will be developed and tried, and, as knowledge and facts gather weight and importance, new specialties will arise The success of each group in delivering to the patient satisfaction in alleviating his ailments will be the guide to the permanency of that group in the world of medical specialists

The borders of most specialties are not clearly defined, and orthopaedic surgery is no exception to this Constant changes in the scope of a specialty will be noted, just as the individuals in that specialty increase their knowledge and skill in the care of certain conditions which may be called borderline As medical knowledge advances by the development of scientific facts, specialties will ultimately tend to become more stabilized Whether we will ever reach a stage of complete stabilization is, of course, speculative Theoretically, such a stage might be reached when our knowledge of scientific facts has become completely evolved

Let me emphasize my belief that, while specialties develop and specialists become more expert in their chosen fields, the need for cooperative effort by specialists in treating many individuals becomes more evident Nothing is more pitiful than the sight of a highly

* Presidential Address read at the Annual Meeting of The American Orthopaedic Association, Colorado Springs, Colorado, May 20, 1949

specialized individual facing some problem entirely outside the limits of his sp without the aid of someone versed in the care of that particular condition.

In tracing the development of the limits of our specialty of orthopaedic surger must of course start with the *Orthopaedia*, a book written in 1741 by Andry, a Pro of Medicine in the Royal College and senior dean of the Faculty of Physick at P Andry coined the term "Orthopaedia" and, despite many efforts to have that t changed, it has remained.

The title page of the English translation of Andry's *Orthopaedia* reveals the follow

"Orthopaedia
Or, the Art of
Correcting and Preventing
Deformities
in
Children
By such Means as may easily be put in Practice by Parents themselves
and all such as are employed in Educating Children
To which is added
a Defense of the Orthopaedia
by way of Supplement by the Author"

The scope of this treatise is broad, covering not only the prevention and correcti of deformities by such means as seemed to the author to be available at that time, b also many phases of what would now be regarded as the work of dermatologists, beau specialists, and teachers of speech correction. Whitman described Andry's work as "in sense a scientific work, even from the standpoint of that time. It was what might be call a nursery guide, in it were considered not only the common postural deformities, but, much greater length, external defects and blemishes as of the hair and skin, which cou not be concealed."

My reading of *Orthopaedia* leads me to be in agreement with Whitman that its scie tific value is doubtful, particularly in the light of present knowledge.

At a later date Bigelow, afterward Professor of Surgery at Harvard, in a dissertatic for the Boylston Prize for 1844, wrote on the question: "In what cases, and to wh extent, is the division of muscles, tendons, or other parts, proper for the relief of deformit or lameness?" Bigelow stated: "It is believed that the general intention of the Committe will be fulfilled by an attempt to cover the ground now occupied by Orthopedic Surgery" In the paper Bigelow covered the following subjects: strabismus, stammering, tenotomy club-foot, torticollis, false "ankylosis" of the knee joint, rickets, permanent flexion of th hip joint, ankylosis, lateral curvature of the spine, contraction of the hand and finger congenital dislocations, and subcutaneous section of the articular muscles.

In a preface to the above-mentioned paper, Bigelow stated that he had consulte the writings of Guerin and others, "especially the *brochures* of M. Guerin, who has bee for some time the leading French orthopedist. . . . It is possible that M. Guerin ha availed himself of the suggestions of previous writers, that, in common with other specia ists, he has overestimated the importance and the efficacy of his art, that he has bee indiscreet in its application, and that 'the division of forty-two tendons, muscles, et upon the same subject' was an audacious undertaking rather than 'a remarkable achieve ment'. But it should not be forgotten that the scientific acquirements and practical ski of this orthopedist are undisputed. . . ."

With the establishment of our Association in 1887, the specialty became somewh better defined. In order to glean some facts as to the recognized scope of orthopaedi surgery throughout the years of existence of The American Orthopaedic Association, have reviewed the presidential addresses of most of the past Presidents of the Associatior In 1894, Phelps stated: "Their work [orthopaedic] was confined to the application c

[illegible] to overcome deformity when it was not considered a sacrilege to do so [illegible] of the ancient *orthopaedist* was, at least, the equal of our present [illegible] in point of ingenuity and intricacy And the braces used at the present time bearing the names of modern men, supposed to be modern inventions, are nothing more [or] less, with but few exceptions, than the revival of the old ideas of the past"

"But the science of surgery did progress, and it gradually made inroads upon the field of the *orthopaedist*, and he soon saw many of his pet deformities, which had been to him through long years a source of pleasure and remuneration, filched by the skilful and investigating surgeon [illegible] Hernia unquestionably should be classified as an orthopaedic object"

In Whitman's presidential address for 1896, entitled, "A Definition of the Scope of Orthopaedic Surgery" he suggested the following definition "Orthopaedic surgery is that division of surgery which treats of disabilities and diseases of the locomotive apparatus and of the prevention and treatment of deformities of the framework of the body" Whitman went on to say significantly "But this Association, as the representative of modern orthopaedic surgery, can be bound to no exclusive method or doctrine, for its object is to bring together and to concentrate individual effort in the search for truth, wherever this search may lead"

Sayre, in 1904 pointed out that "In many parts of Europe the orthopaedist is synonymous with the instrument maker, and has the same relation to the man whom we in this country understand as an orthopaedist as the oculist bears to the ophthalmologist"

Brackett in 1905, stated that "One of these directions of development is particularly evident, and one day of our program has been set aside for the consideration of this branch of orthopaedic work I am referring here to the application of orthopaedic work to adult cases, or, as it is beginning to be called, Adult Orthopaedics"

Turning to the writings of Sir Robert Jones, we find the following "There was a time when orthopaedic surgery included a comparatively small group of cases Lateral curvature, flat feet, rachitic distortions, club feet, and a few other congenital conditions represented the list Apart from tenotomies and an occasional osteotomy, no other operations were indicated The use of the knife was almost a reproach, and only followed a failure in mechanical effort How different it is to-day, when some of the most difficult operations in the domain of surgery are included under the definition 'orthopaedic'! During the great war I had to direct—on behalf of the British Government—what was known as military orthopaedic surgery, and this involved a statement of what groups of cases ought to be included under the term

"This definition developed into

1 Fractures—recent, malunited, and ununited
2 Deformities of the extremities and spine
3 Diseases, derangements, and disabilities of the joints, including the spine
4 Injuries of peripheral nerves"

It is my feeling, and I think the feeling of most of you, that Sir Robert's skill in organizing the work of orthopaedic surgeons in World War I and later in England has done more than any one thing to bring orthopaedic surgery to its modern status in the English-speaking world

Platt later attributed to Sir Robert Jones the following definition of orthopaedic surgery "The treatment by manipulation, operation, re-education, and rehabilitation, of the injuries and diseases of the locomotor system" Platt went on to point out that "a field so defined is not in the strict sense an anatomical or regional specialty The definition hints at an intimate concern with function It proclaims that we embrace a wide range of therapeutic techniques"

Other definitions of the scope of orthopaedic surgery have been formulated from time to time, such as that in Article I of the By-laws of The American Orthopaedic Association

specialized individual facing some problem entirely outside the limits of his sp[ecialty] without the aid of someone versed in the care of that particular condition.

In tracing the development of the limits of our specialty of orthopaedic surgery [we] must of course start with the *Orthopaedia*, a book written in 1741 by Andry, a Pro[fessor] of Medicine in the Royal College and senior dean of the Faculty of Physick at [Paris]. Andry coined the term "Orthopaedia" and, despite many efforts to have that [term] changed, it has remained.

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With the establishment of our Association in 1887, the specialty became somewhat better defined. In order to glean some facts as to the recognized scope of orthopaedic surgery throughout the years of existence of The American Orthopaedic Association, I have reviewed the presidential addresses of most of the past Presidents of the Association. In 1894, Phelps stated: "Their work [orthopaedic] was confined to the application of

satisfactory manner. Some phases of our specialty may have reached a point of stabilization and standardization which would permit definition, but many parts of the specialty are changing from decade to decade and from year to year, so that we may have difficulty in recognizing the work of a few years ago. Indeed, I think that much of the interest in the specialty would be lost, were it to become stabilized and standardized. Certainly the reason for our Association's existence is to learn from each other about methods to improve the diagnosis and treatment of orthopaedic conditions, and if a day of such standardization is reached that the specialty has nothing new to offer in methods or ideas, then our very existence as an association will be in danger of deterioration and decay.

In all our plans for the future of the specialty, the position of The American Orthopaedic Association should be one of leadership, active, alert, and decisive. Such leadership can be maintained only by an energetic group of active members, all willing to go out of their way to see the specialty develop to its greatest possibilities. Some may exert their influence through teaching, others through writing, and others through organizational work. Our active membership has remained about the same for almost twenty years, and it is time we give thought to its enlargement, in order to take into our ranks more of the better young orthopaedic surgeons, of whom there are many.

The letter of the late Arthur G. Davis as chairman of the Membership Committee should have reminded all members of their responsibility in seeing that names of likely candidates for membership are properly proposed and sponsored.

It is my feeling that many of our members do not take the work of the Association in a serious vein. We need the active and thoughtful participation of everyone in all phases of the Association's work, in order to maintain the leadership which should be ours. This Association is not a club of honorary attainment, meant for basking in the glories of one's past, but a medium for active participation and planning by everyone now a member, and for the future activity of a number of young men whose ability is recognized and who should be taking an active part in the work.

Thus, with an enlarged and active group of men capable of leadership, we can point the way toward the development of newer ideas in orthopaedic surgery and can strive to improve it in every way, such as in practice, research, and teaching.

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CONTROL OF BONE GROWTH BY EPIPHYSEAL STAPLING

A PRELIMINARY REPORT*

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From the Milwaukee Children's Hospital

When Phemister reported the operative arrest of longitudinal growth of bone in 1932, a new principle was introduced in the correction of excessive length and angular deformity of extremities. Previous to this time, bone-shortening operations[16] had been used to a limited extent to equalize limb length. These procedures were only slightly less extensive than those for bone lengthening[1, 2, 11] and, like them, were attended by the risk of grave complications. Growth was an uncontrolled force which had to be considered. Phemister utilized this growth factor in an operation of much less magnitude.

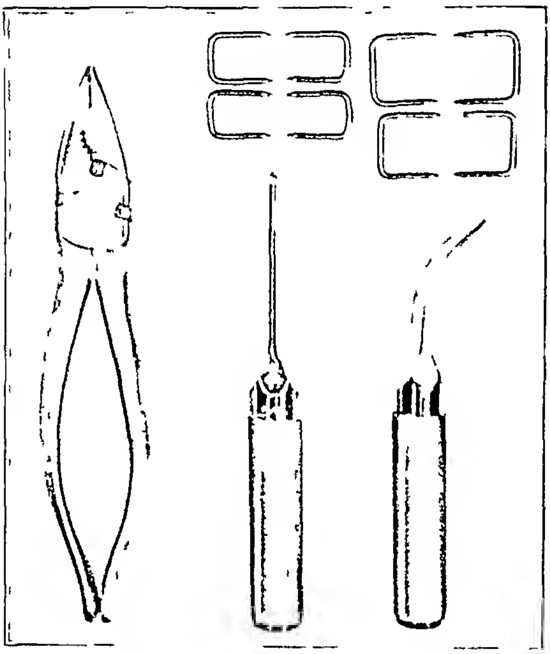

FIG. 1

Staples of three thirty-second-inch 317 M stainless steel. The legs are three-quarters of an inch long, the cross members are five-eighths and seven-eighths of an inch. Modified pliers and set help place the staples close together. The extractor is necessary for removing the staples.

Another advance was made in 1945, when Haas proposed the retardation of bone growth by a wire loop. He tried this first in laboratory animals and later in children, and proved that longitudinal growth at an epiphysis could be held back mechanically with a wire loop. Even more important, he proved that growth was resumed when the wire broke or was removed. The implications were tremendous. Instead of attempting to compute the probable future growth of both extremities and to arrest growth at the proper time, Haas suggested earlier temporary arrest. He proposed removing the retentive wire when the deformity or inequality of length had been corrected sufficiently.

Stimulated by this work of Haas, in 1944 we began to employ rigid staples of the type popularized by R. E. Burns. The method of epiphyseal stapling was reported by one of us (W. P. B.) at a meeting of the Chicago Orthopaedic Society on December 14, 1945, and was published by Hodgen and Frantz. Haas continued his experimental work on dogs, using staples rather than wire loops[6].

Staples were used in American bone surgery in 1906[3], and Venable and Stuck report that they had been employed in Europe long before that time. Notching or roughening them to prevent extrusion has had many ramifications. When they are to be used for growth control, it is important that they may be removed without traumatizing growing bone. Simple, smooth wire staples have been used to date. Various sizes and gauges of wire have been tried. The authors are now using three thirty-second-inch rods of 317 M stainless steel with a Rockwell hardness between 33 and 35 C. Staples are beveled on the outer sides and formed cold with dies under hydraulic pressure. Two sizes are adequate for use in the femur and tibia. The legs should be three-quarters of an inch long,

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 26, 1949.

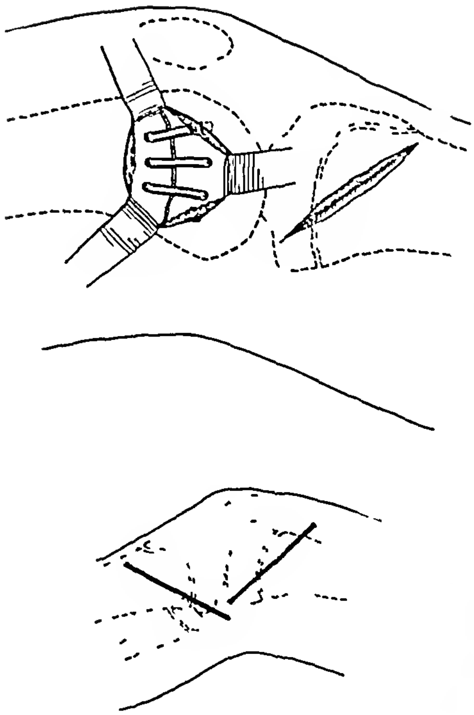

FIG 2

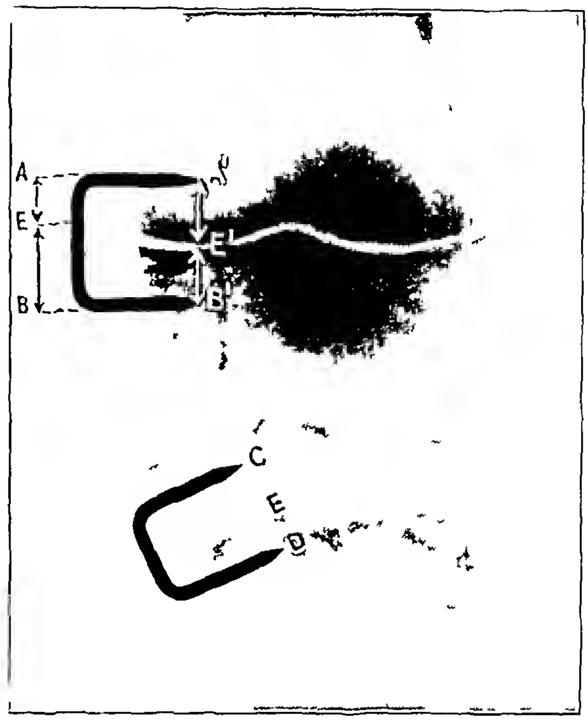

FIG 3

Fig 2 Oblique incisions are most satisfactory, they afford adequate exposure and cause less scarring

Fig 3 The epiphyseal plates undulate, as seen in both projections (See Figs 8-D and 10-B for lateral views) For the legs of the staples to be equidistant from the femoral epiphyseal plate, it is necessary that AE be considerably less than EB Then $A'E'$ will approximately equal $E'B'$ At the proximal end of the tibia, it is necessary to include more of the epiphysis, which is cancellous bone CE should be greater than ED

the cross member five-eighths or seven-eighths of an inch (Fig 1) The smaller staple is used in the proximal end of the tibia, the larger one in the distal end of the femur If the growth of the fibula or other smaller bone is to be similarly controlled, a smaller staple will be desirable

Further experimentation may suggest a more efficient mechanical design which will still be compatible with quantity production A physicist, a mechanical engineer, and their co-workers have been interested in the problem Many helpful suggestions have been made by orthopaedic surgeons who have tried out the method, further comments will be most welcome The use of a single heavy staple has been proposed frequently This would displace more bone and would require greater accuracy of placement The method would be less adaptable, and insertion of the staple in the proximal end of the tibia might be difficult

Excessive bending and extrusion are mechanical problems which are easily solved by the use of an adequate number of staples To date, no serious complication has occurred from a staple pulling out It is a simple matter to remove, reinsert, add, or move staples Patients must be followed closely, so that any mishap may be detected and remedied It is wise to do the stapling while there is still sufficient growth potential to permit correction of any inadvertent angular deformity

If one staple is inserted on each side of the end of a long bone so as to bridge the epiphysis medially and laterally, the staples will bend and break (Fig 4-B) If two staples are used, they will bend (Fig 6-D) and occasionally break In this manner the growth is only temporarily or inadequately retarded If three staples are inserted on each side of an epiphysis, growth will be stopped immediately and almost completely The staples will usually bend slightly There is some drifting or slipping, like wire cutting through a piece of ice, but this is negligible in relation to the shortening to be obtained It may even be

Fig 4-A

Fig 4-B

Fig 4-A J B, aged eleven October 8, 1945, three months after stapling One staple on each side will bend Note that the maximum bending is in the soft epiphyseal bone

Fig 4-B Three months later (January 7, 1946), the staples had broken Three weeks after this roentgenogram, the fragments were left in as markers and new staples were inserted

Fig 4-C

Fig 4-D

Fig 4-C May 6, 1946 Four months later, and three months after insertion of new staples

Fig 4-D May 24, 1948 Twenty months after removal of the last staples, and twenty-seven months after insertion of the second group of staples There had been 1 1 centimeters of growth since Fig 4-C was taken 0 3 centimeter occurred during the time the staples were in place (slippage and bending), 0 5 centimeter in the first three months after removal, and only 0 3 centimeter in the next thirteen months In the next ten months there was no growth, although this roentgenogram shows that the epiphyseal plate is just closing

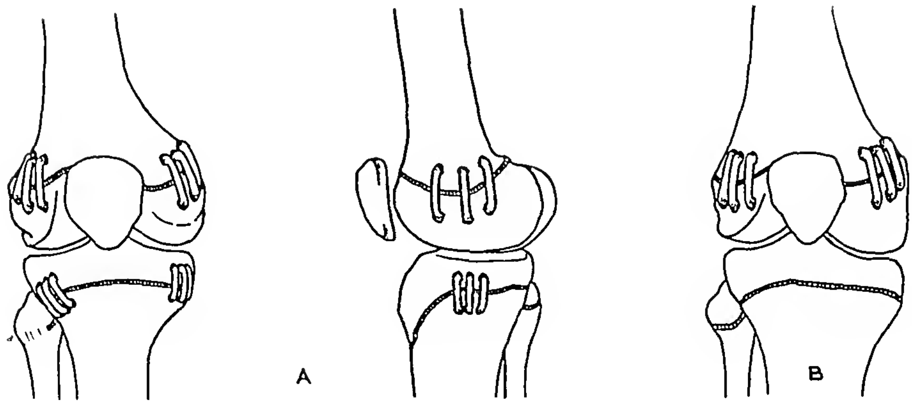

FIG 5

Diagrammatic representation of the control of linear growth Three staples are a unit
A Total involvement Femur and tibia are both too long
B Femoral involvement Only femur is too long

desirable to allow some slipping, so as to maintain the viability of the epiphyseal plate Complete arrest might cause premature epiphyseal closure More efficient staples will be tried out experimentally

The authors' routine is to use three staples as a unit unless there is a reason for another combination Interesting growth changes can be obtained In a long lower extremity with knock-knee, one may put three or four staples on the medial side and one or two on the lateral aspect The drift on the lateral aspect will equalize the knock-knee at about the time the inequality of length is overcome

OPERATIVE TECHNIQUE

The extremity is shaved and washed from ankle to groin on the day preceding operation A tourniquet is applied at the mid-thigh, the knee is prepared surgically, and the foot is wrapped in a small sheet The knee is supported on a block in flexion of 30 to 70 degrees Medial and lateral incisions, 5 to 8 centimeters long (depending upon the amount of subcutaneous fat) are made obliquely through the skin and subcutaneous fat centering over the epiphysis to be stapled Above the knee, the incisions should slant from anterior-proximal to posterior-distal, below the knee, from posterior-proximal to anterior-distal (Fig 2) The scarring is less if two incisions are used instead of a single long one, for exposing simultaneously the femoral and tibial epiphyses The deep fascial layers are split in the direction of their fibers and the periosteum is exposed Mobile soft parts must not be impaled

Staples may be inserted "blind" without actually cutting through the cartilage cap and exposing the epiphyseal plate Roentgenograms in two projections are imperative After the position has been verified, it is often a good plan to cut the periosteum and cartilage along the cross members of the staples and to sink the staples flush Some surgeons will prefer to incise the periosteum and overlying cartilage and raise two flaps, so as to expose the epiphyseal plate In children under ten, thick flaps are necessary It is not desirable to bury the staples deeply, if they are to be removed

The easiest approach is at the medial aspect of the distal femoral epiphysis With the knee flexed, the vastus medialis need not be split It is displaced anteriorly, while the hamstring tendons fall posteriorly The movable fascial layers are split in the direction of their fibers By sharply flexing the knee, the posterior aspect of the femoral condyle may be reached without difficulty By straightening the knee and strongly retracting the vastus, staples may be placed anteriorly

Exposure of the lateral aspect of the distal femoral epiphysis is only slightly more difficult It is a mistake to incise the fascia lata with the knee extended With the knee flexed, the thin dorsal expansion of this fascial layer may be split longitudinally, just

dorsal to the iliotibial tract, which is then retracted posteriorly. The vastus lateralis is displaced anteriorly without division of any of its fibers. The mobile soft parts may be retracted easily to expose the condyle, either anteriorly or posteriorly.

Below the knee, it is necessary to cut more of the soft tissues. On the lateral aspect of the tibia, the deep fascia is split longitudinally, just anterior to the head of the fibula. The incision is developed by elevating the fibers of the extensor digitorum longus from the fibula and the tibiofibular ligament. Through this incision, staples may be inserted on the lateral and posterior aspects of the tibia. Posterior staples must be tilted anteriorly, to keep the distal leg of the staple from missing the bone and protruding into the popliteal space. If the staples must be placed anteriorly, they are best inserted "blind", just posterior to the tonguelike projection of the epiphysis. The thick ligamentous tissue can then be split along the cross member, and the staple can be buried. It requires some care to keep the staples from protruding into the knee joint.

It should be noted in the roentgenograms that the epiphyseal plates undulate. To obtain maximum efficiency, the staples are placed slightly farther distally on the femur than would appear necessary from the peripheral level of the cartilage. At the proximal end of the tibia, the center of the staple must be slightly proximal (Fig. 3). At the distal end of the femur, anterior or posterior staples must be inserted somewhat proximal to the middle ones (Fig. 5).

While the roentgenograms are being developed, the proximal fibular epiphysis is exposed by elevating the periosteum on the anterior aspect. The peroneal nerve is guarded by bone-elevating retractors. One-half or more of the epiphyseal plate is curetted away. A few bone chips from the metaphysis may be inserted into the defect. It is certainly undesirable to let the fibula grow too long, but there is no particular disadvantage in having it slightly short. Simple curetting has proved so satisfactory that the writers have not used staples at this epiphysis, although they would be preferable in a young child. Staples of the standard sizes are too large for this purpose.

On the medial aspect of the tibia, an oblique incision splits the anterior fibers of the pes anserinus. The tendinous expansion of the sartorius and gracilis may be retracted posteriorly for anterior or medial insertion, but cannot well be mobilized for posterior placement.

If the surgeon wishes, and particularly if the staples are to remain in permanently, the epiphyseal plate may be exposed. A one-inch

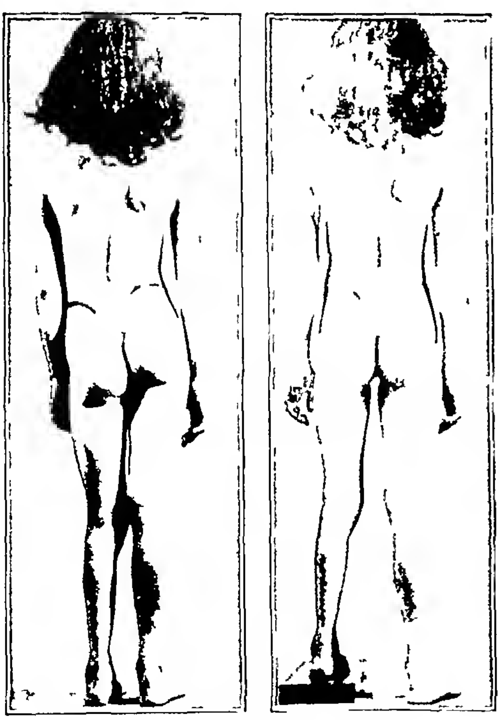

Fig. 6-A

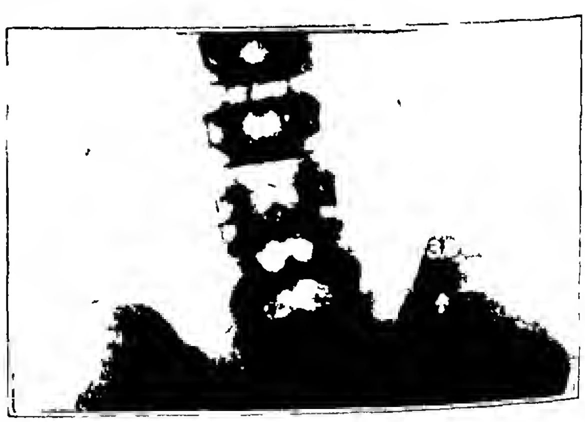

Fig. 6-B

Fig. 6-A: H. H., aged nine. April 3, 1946. Patient has short left tibia following poliomyelitis; triple arthrodesis of left foot has been done. Elevation of one and one-half inches fails to level the pelvis.

Fig. 6-B: April 3, 1946. Roentgenogram, by White technique, demonstrates total shortening, pelvic tilt, and functional curve.

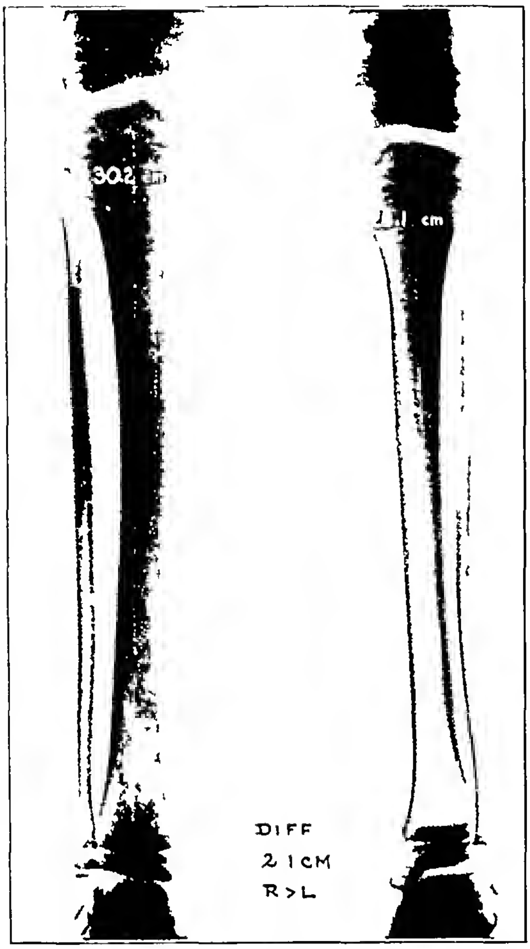

FIG. 6-C

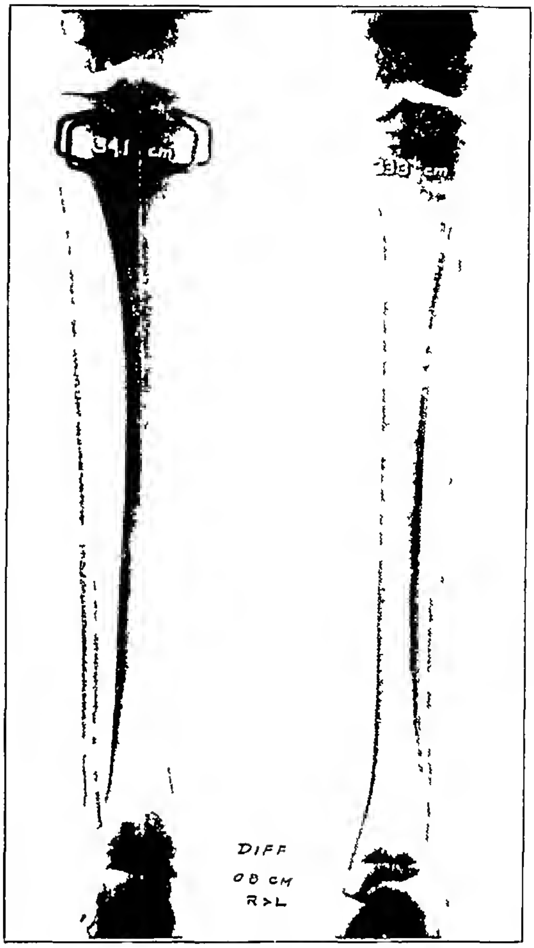

FIG. 6-D

Fig. 6-C. April 3, 1946. Roentgenogram at six-foot distance, before stapling.

Fig. 6-D. December 11, 1948. Roentgenogram at six-foot distance, thirty months after stapling. Staples have bent. Three staples should have been used on each side instead of two.

Fig. 6-E. December 11, 1948. Six-foot roentgenogram, by White technique, indicates that total shortening had been reduced to 2 centimeters. This is almost enough correction, because of the drop-foot on the left.

Fig. 6-F. December 11, 1948. Thirty months after stapling, gait had improved. A lift of three-quarters of an inch completely corrects the pelvic tilt.

FIG. 6-E

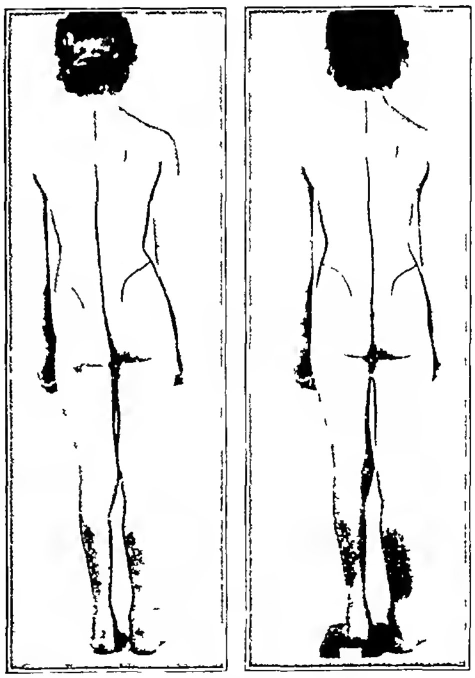

FIG. 6-F

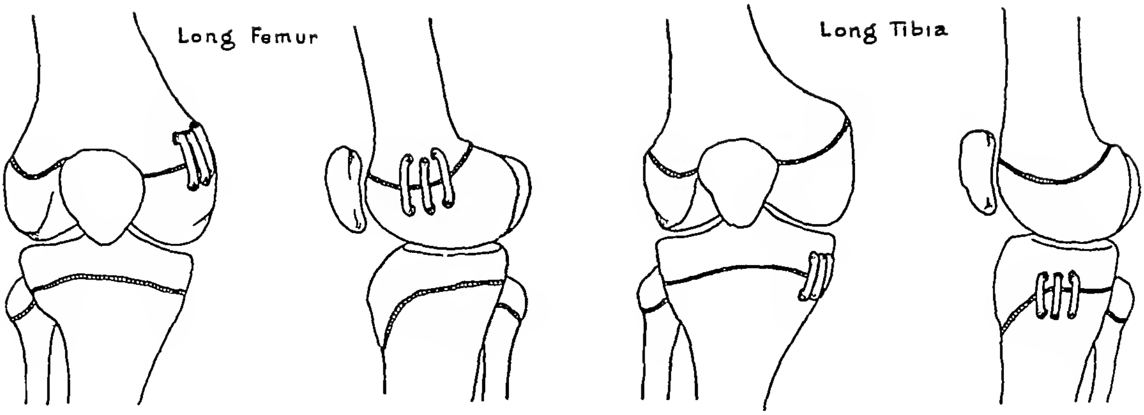

FIG 7

Diagram of staples placed to correct knock-knee Femoral and tibial epiphyses could both be stapled in an extreme case

longitudinal incision is made through the periosteum and the cartilage cap Short crosscuts are made at both ends of this incision With a thin osteotome, which is curved on the flat, two flaps are raised, exposing the epiphyseal cartilage It is important to center the staples accurately in the anteroposterior direction Displacement forward (Fig 10-C) will result in back-knee, while a backward location will produce the opposite deformity Three staples are driven so as to bridge the epiphyseal line Special instruments are not necessary An inserter or specially prepared pliers and a set (Fig 1) will facilitate the operation and permit the insertion of staples close together through a small incision

After all of the staples are in place, roentgenograms are taken in both the anteroposterior and lateral projections A true lateral view is necessary to prove that both legs of a posterior staple are actually in the cortex of the femur or tibia If any staple is placed incorrectly, it may easily be withdrawn For this purpose, a special wedge-shaped, curved-on-the-flat extractor is desirable The extractor should be driven under the staple, so as to avoid damage to the epiphyseal plate The staple is then reinserted with the other staples as guides Roentgenograms in two projections are taken again

After the exact location of the staples has been verified, the wounds are closed in layers As is customary following epiphyseodesis, a cylinder cast was applied for three weeks in our earlier cases When short oblique incisions are used, this is not necessary

By experience, the authors have learned

1 To use staples of appropriate size,

2 To use three staples as a basic unit,

3 To study carefully the undulations of the epiphyseal plate in the preoperative roentgenograms (Fig 3),

4 To obtain accurate roentgenograms in both anteroposterior and lateral projections *in the operating room*

REMOVAL OF THE STAPLES

The old incision is opened or the scar is excised If the staples have been driven through the periosteum, it is an easy matter to locate and remove them If the staples have been buried and considerable bone has grown over them, removal is more difficult than insertion The periosteum is elevated and chips of bone are removed tangentially with a chisel Probing with a straight needle is sometimes helpful If the staples are not discovered immediately, they should be located by roentgenograms Markers are inserted and roentgenograms taken in the anteroposterior and lateral projections More bone may then be removed, but mutilation of the epiphysis is not necessary No growth arrest has been encountered, even if considerable bone has been removed Care has been taken not to replace bone, which would produce a grafting effect across the epiphysis

After the cross member of a staple has been uncovered, it is an easy matter to drive the wedge-shaped extractor under it and to "break out" the staple. Extraction with a periosteum elevator or any ordinary instrument is difficult.

COMPLICATIONS

Before the necessity of biplane roentgenograms in the operating room was appreciated, avoidable errors in technique were made. One staple was left protruding into the knee joint. It was removed and reinserted without subsequent ill effect. On several occasions, the posterior staple at the proximal end of the tibia or the distal end of the femur was wrongly placed. One leg of the staple failed to engage the sloping cortex of the bone. Aiming the staple toward the center of the bone will avoid this mistake, and will also prevent the points of the staples from protruding into the popliteal space. Any such error in technique should be discovered in the operating room; it is easily remedied by reinserting the staple. If later roentgenograms show that one of a group of staples does not change while the adjacent staples start to spread, there is proof of improper insertion of the staple with parallel legs.

Angular deformity and overcorrection have occurred when the patients have failed to report regularly for observation. The serious deformities reported by Straub, Thompson, and Wilson, Regan and Chatterton, and others have not been observed. Deformities which are produced by mistakes of prediction or of technique may be corrected without osteotomy by rearranging the staples, if the child continues to grow.

DISCUSSION

In 1862, Hueter noted the relatively greater growth of bone structures which are under diminished compression. Seven years later, Volkmann laid the foundation for epiphyseal stapling when he referred to the observation of Hueter and added that abnormal differences of compression cause unequal, asymmetrical growth of a joint. On the side where pressure is abnormally increased, growth is retarded.

There is no doubt that growth may be arrested by epiphyseal stapling (Figs. 6-A to 6-F, 8-A to 8-D, 9-A to 9-E, and 10-A to 10-D), and that growth is resumed when the staples have been removed (Figs. 4-A to 4-D). Two questions were raised by Haas[6] with regard to the progress after removal of the staples: (1) Is growth less rapid than would ordinarily be expected? (2) Is growth terminated earlier? We can answer these questions in part.

In most children prolonged observation after removal of the staples will be futile, as growth will stop within a year or two. In thirteen cases the staples have been removed for six months or longer. It might seem expedient to chart the subsequent epiphyseal growth as compared with that on the "normal" side. Of the thirteen cases, however, only seven operations were performed primarily for linear deformity and six for angular deformity. In several cases, both deformities were

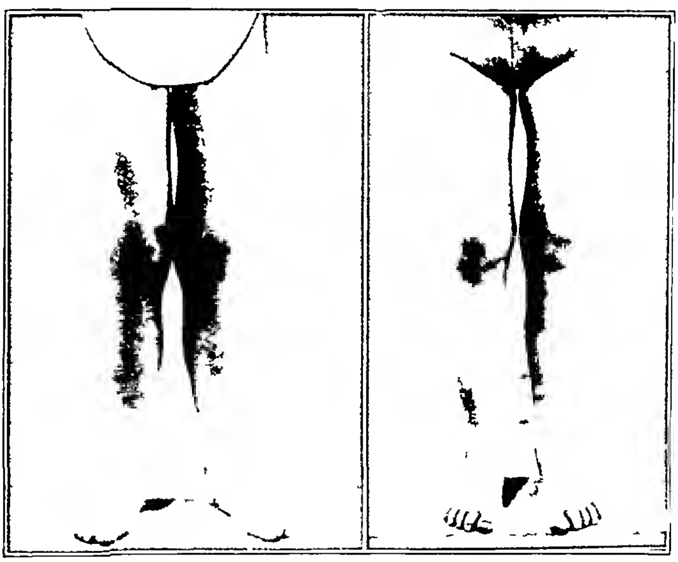

FIG. 8-A FIG. 8-B

Fig. 8-A: G. O., aged nine, October 11, 1948. Photograph of patient with hereditary knock-knee, before stapling.

Fig. 8-B: February 7, 1949. Three months after stapling there was complete correction of knock-knee.

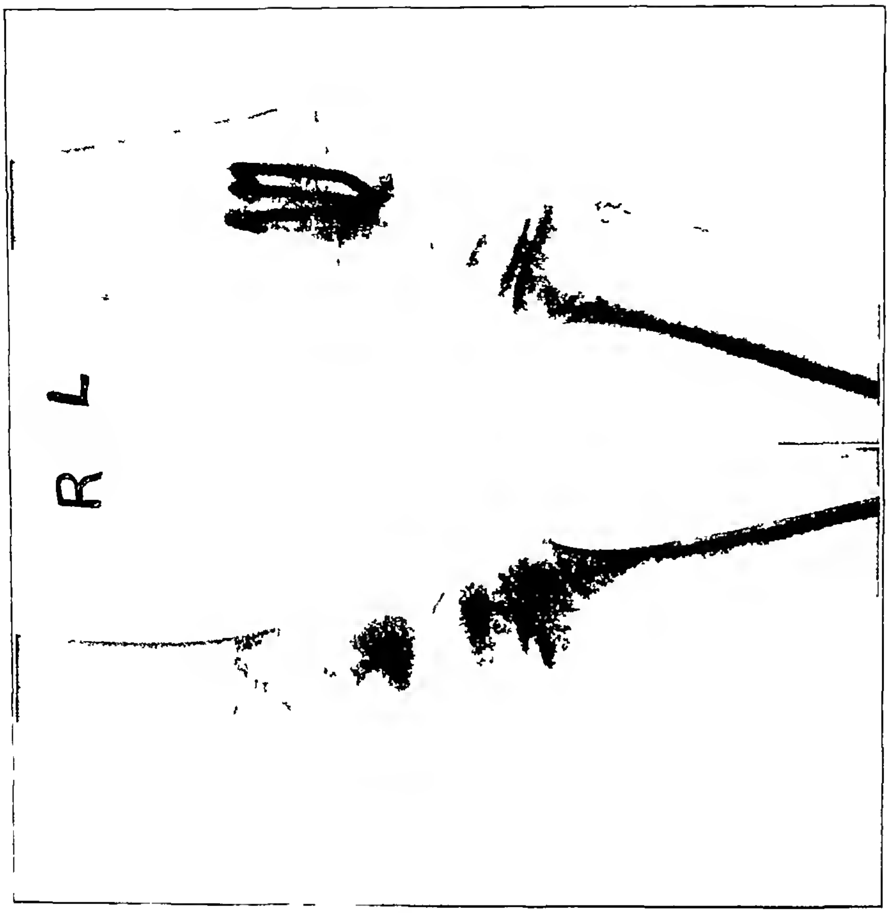

Fig 8-D

Fig 8-C

February 7, 1949 Valgus had been corrected Staples were ready for removal

present and were corrected simultaneously Even if we consider only the linear cases, the figures become meaningless Either the stapled side is abnormal (osteomyelitis, Figs 9-A to 9-E), or the opposite side is atrophic (poliomyelitis, Figs 6-A to 6-F), has a mechanical derangement of the epiphysis (trauma), or in some other way is vitiated as a control

More significant is the observation of the six cases of angular deformity in which stapling was done on one side only All of the extremities were symmetrically aligned with the opposite side at the time the staples were removed (Figs 8-A to 8-D and 10-A to 10-D) There has been no change of alignment since

In two cases, markers were left *in situ* after removal of the staples In one girl, aged fourteen, the distal femoral epiphysis grew 5 millimeters in the first three months In the following thirteen months it elongated only 3 millimeters In the next ten months there was no growth on either side, although the epiphyses remained open until the termination of this period A second girl, aged seven, grew 2 3 centimeters at the distal femoral epiphysis in the first ten months after removal of the staples Such variations are probably due to temporary growth spurts and not to the previous stapling

It is difficult to confirm clinically the excellent experimental work of Haas[6] We agree when he says "It is difficult to determine definitely whether or not growth is as active after temporary retardation by a wire or staples It was not so active as on the normal side, but it is possible that injury to the circulation and trauma to the plate disturbed the growth There was evidence of premature closure of the plate in some of the experiments "

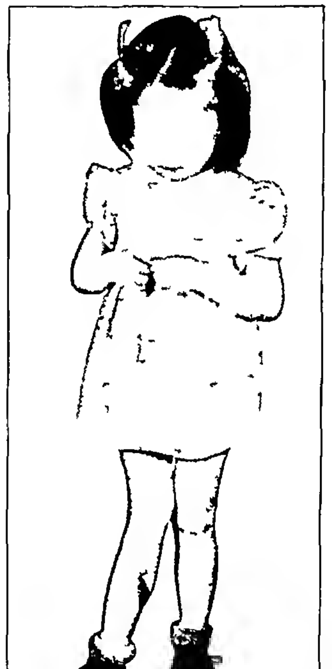

Fig 9-A

D G , aged seven November 7, 1946 Chronic osteomyelitis of right tibia with overgrowth, valgus knee, and valgus foot

Growth is "not so active as on the normal side" in his dogs, but in children it is not infrequently *more* active An epiphyseal plate which has become thin as a result of stapling rapidly regains its former thickness after removal of the staples Growth is temporarily accelerated, probably due to the stimulus of the operation for removal of the staples There should be nothing in this operation to retard growth Significant epiphyseal injury has not been observed Haas's staples were very large for the size of the bones The trauma to the epiphysis which he mentions need not occur in children His observations on unilateral stapling in puppies, with large staples, are not applicable when three-quarter-inch staples are used in children Clinically, the effect on longitudinal growth is less and the correction of angular deformity is more than Haas observed when his unilateral staples extended clear across the bone

In our early personal communications, no untoward epiphyseal closures were reported We have had none yet Whether staples are removed or left *in situ*, epiphyses which have been operated upon usually fuse from two to six months early This acceleration of a developmental process is probably due to the stimulus of the operation and not specifically to the stapling It comes at a time when growth on the other side is minimal or absent, and is not very significant

Those who want tables and graphs to prove the rate of growth after removal of staples should consider the following example A ten-year-old child breaks one femur in the middle third Healing occurs with bayonet apposition and one centimeter of shortening One of three things may happen

1 The bone will probably overgrow, due to the stimulus of the fracture Accurate measurement at the end of six months will show that the femora are about equal in length

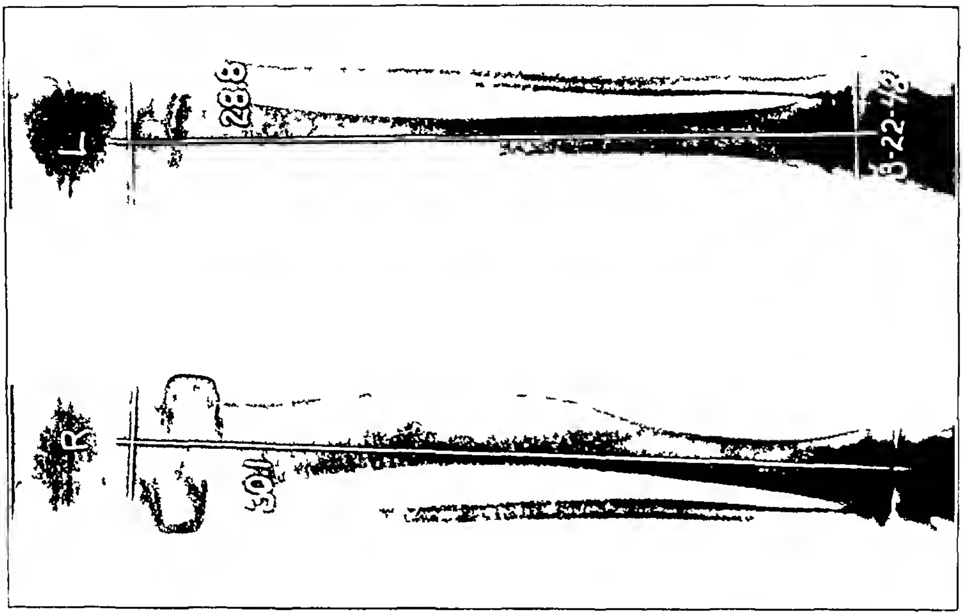

Fig 9-D

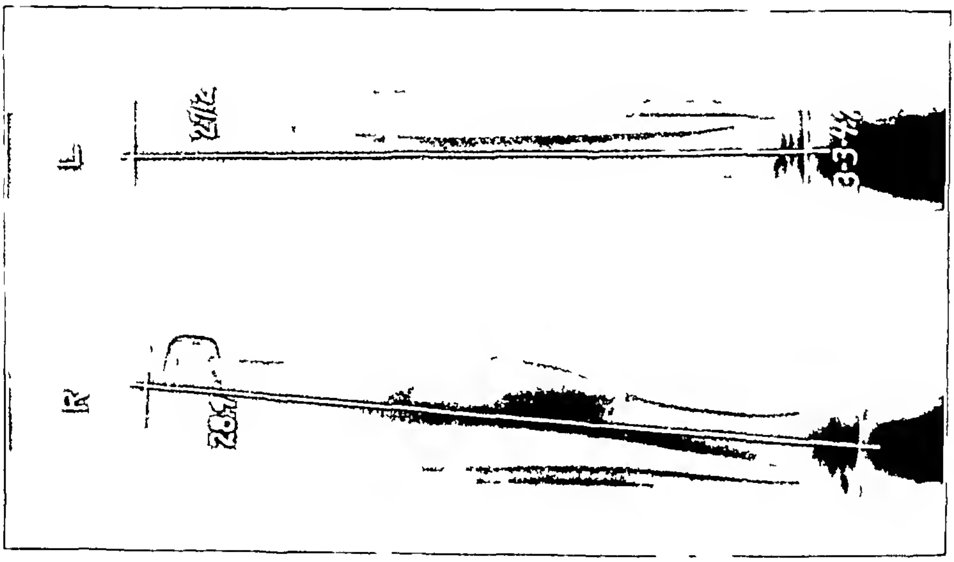

Fig 9-C

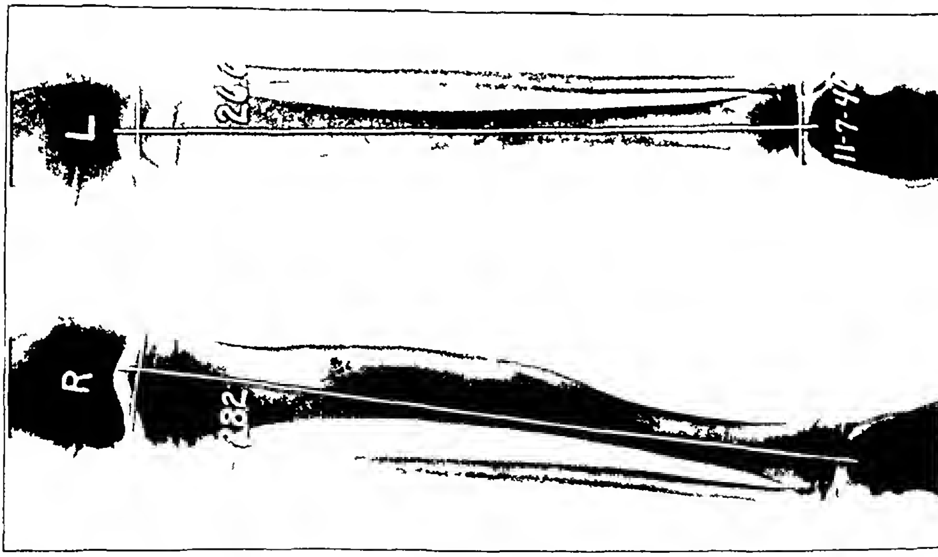

Fig 9-B

Fig 9-B November 7, 1946 Anteroposterior roentgenogram shows angular deformity on right side The difference in length of the tibiae was 1 6 centimeters

Fig 9-C March 3, 1947 Four months after stapling, the angular deformity had been corrected The linear deformity was unchanged Staples were then inserted on the lateral aspect

Fig 9-D March 22, 1948 One year after second stapling, linear deformity had been corrected by 0 3 centimeter

2 There may be no overgrowth of bone, but persistent shortening of about one centimeter

3 There may be excessive overgrowth of bone, so that the injured femur is as much as one inch too long When the results of a simple fracture in a normal bone vary so much, we can attach little value to statistical studies of growth increment in abnormal bones

The best way to test growth after the removal of staples is to watch a case of idiopathic knock-knee in a boy of ten to twelve years In a boy of this age there is little tendency to further change in angulation If three staples are inserted on the medial aspect of each distal femoral epiphysis, the deformity will be completely corrected in from three to eight months (Figs 8-A to 8-D) The exact time depends upon the extent of the deformity and the rate of growth during the control period If the staples are then removed and photographs and roentgenograms are taken, a record of the straightness of the lower extremities is established If the existing state is maintained, then we have clinical proof that essentially normal growth of the epiphysis has been resumed The untouched lateral aspect of each epiphysis acts as a control Two such cases have been observed for ten months or longer without change in alignment If several such cases are observed until growth has ceased, we shall have valuable proof to report in a future paper

"More difficult than the actual technical procedure is the decision as to when the operation should be performed and which epiphyses should be fused " This was the decision of Wilson and Thompson, after describing an elaboration of Phemister's technique with the removal of large grafts, curetting, and cauterization of much of the epiphyseal plate Stapling simplifies the operation, and it also answers their questions

The operation should be performed several years earlier than appears necessary from the actuarial charts It should be performed at a time that is convenient to the patient, the exact date makes little difference When the deformity has been corrected, the staples are removed

Fig 9-E

December 18, 1948 Nine months later, additional correction of 0 3 centimeter had been obtained (total correction of the tibiae of 0 6 centimeter)

The decision as to which epiphysis to staple is no longer a serious matter Both the proximal tibial and the distal femoral epiphyses should be stapled When the individual bone is of the proper length, the staples are removed

Sixteen years after the publication of Phemister's article, there is still no unanimity as to a method of estimating growth White's simple annual increment [17], the percentage factor of Wilson, Thompson, and Straub [13,18], and the various tables and graphs of growth expectancy of Green and Anderson and others are all inadequate in the face of individual variations We have not discarded these approximations, they furnish valuable help in planning stapling operations When the staples are in, however, further decisions are

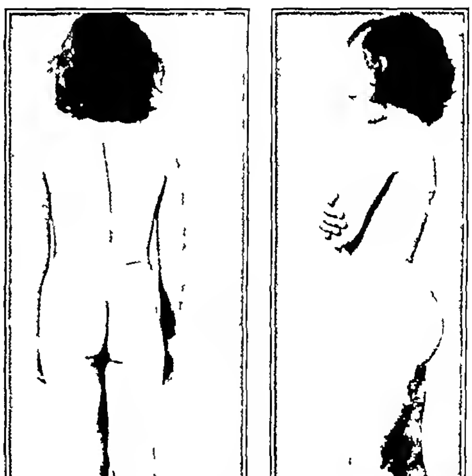

Fig 10-A

C P, aged nine February 4, 1948 This child had had monarticular atrophic arthritis of the left knee at the age of two years The active process subsided, leaving flexion deformity of 25 degrees of the left knee and overgrowth of the left femur

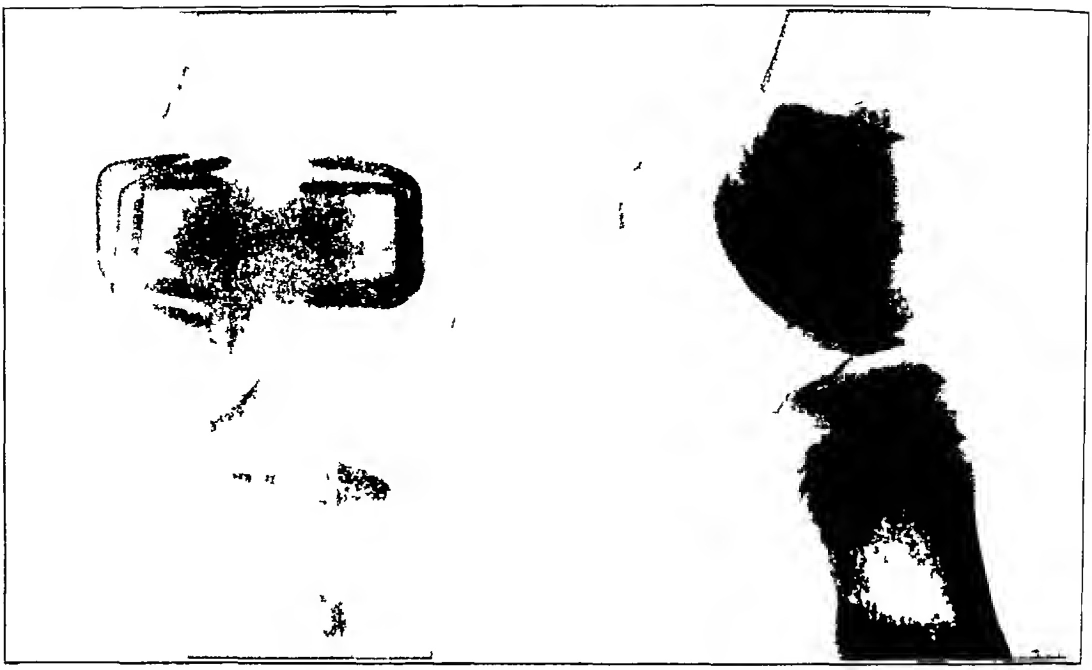

FIG. 10-B

Fig. 10-B. June 11, 1948. Four months after stapling to correct both linear and angular deformities.

Fig. 10-C. Diagram of staples placed to correct overgrowth and flexion deformity simultaneously.

Fig. 10-D. January 5, 1949. Staples were left in place ten months. Photographs, taken one month after removal, show that left knee is straight and pelvis is level.

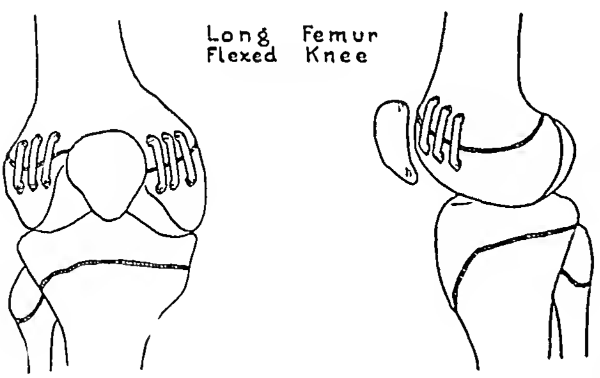

FIG. 10-C

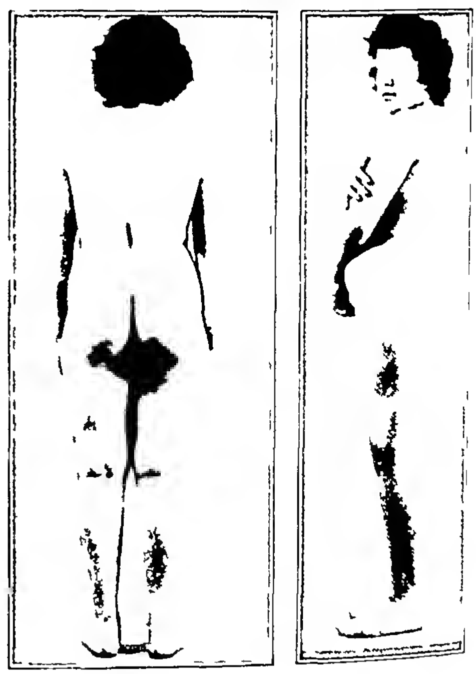

FIG. 10-D

based upon clinical observation and not upon calculation. Actually, only two precautions are necessary to ensure successful timing. (1) The staples must be inserted early enough (but not usually before eight years) to assure correction before growth is completed. (2) The patient must be observed frequently, so that the staples may be removed at just the right time.

The indication for removal of staples is not determined by measurement, but by watching the patient walk. This is particularly true when an unstable hip, stiff knee, drop-foot, or other abnormality influences the decision. It is helpful to have the patient remove the shoe on the side of the longer extremity, so that the effect of further shortening may be observed. In the presence of multiple deformities, the removal of staples becomes the "micro-adjustment" of disability correction. With increased experience, we frequently operate for discrepancies of length that are less than the average error in prediction by the actuarial method.

We do not know how long one may safely leave staples *in situ* with the assurance of growth after removal In 1945, Phemister[10] suggested that the interval be limited to two years In adhering to this rule, we have encountered no untoward epiphyseal closures It is probable that a longer interval is safe in most cases Further studies will be made with reference to this important point

CONCLUSIONS

1 Efficient stapling of the distal femoral and proximal tibial epiphyses stops the elongation of bone at these epiphyses immediately and almost completely

2 The operation is less extensive and the risk of complication is less than with other operative methods of controlling bone growth

3 Angular deformity may be corrected during the growth period Knock-knee, bow-leg, back-knee, flexion deformity, or combinations of these deformities are rapidly overcome

4 The occasional complicating irregularities of growth following stapling should be detected clinically and corrected immediately by rearrangement of the staples

5 After removal of the staples, growth at the epiphysis is resumed at about the same rate as would be expected on the other side, if both sides were normal It is sometimes faster and sometimes slower The variations in rate are usually caused by factors other than staples

6 The best proof of the normal rate of growth after removal of staples is the persistence of a straight extremity after correction of an idiopathic knock-knee

7 Several important questions are being studied further

A What is the ideal size and design of staples?

B For what length of time and for what ages is it safe to leave staples in place?

C What are the factors influencing epiphyseal closure?

D What is the rate of growth after removal of staples which were inserted for various conditions?

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PREDICTION OF UNEQUAL GROWTH OF THE LOWER EXTREMITIES IN ANTERIOR POLIOMYELITIS *†

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One of the more important deformities caused by poliomyelitis is unequal growth of the lower extremities Operations such as epiphyseal fusion, limb lengthening, and limb shortening have been designed for controlling or correcting this unequal growth In conjunction with these operations, normal growth in the epiphyses has been studied, so that epiphyseal growth can be predicted with considerable accuracy No methods, however, have been available for ascertaining in poliomyelitis the expected amount of inequality of growth In this study, we have attempted to evolve a method of predicting the amount of inequality in the length of the lower extremities that might be expected in a case of poliomyelitis The records of 820 cases from the Infantile Paralysis Clinic at Massachusetts General Hospital have been reviewed An intensive study has been made of those patients in whom the disease developed in childhood and who have now reached adult stature

Comparison was made between the amount of growth of the lower extremities and factors that might affect growth, such as age at onset, relative muscle power of the two extremities, operations, deformities, braces, and skin temperature It was apparent that two major variables were related to inequality of growth The first of these was the age at onset of poliomyelitis, and the second, the amount of paralysis in the two extremities Deformities, braces, variations in skin temperature, stabilization operations, and tendon transplants had no predictable effect on growth in the extremities

No inequality in length of the extremities can ensue if poliomyelitis occurs after the epiphyses have closed The time of epiphyseal closure is so inconstant that this study was limited to those patients in whom the onset was before the age of eleven and who have now reached adult stature

To ascertain the effect on growth of the second major variable, paralysis, several groups of cases were studied The first group included sixty-four adults who had had poliomyelitis before the age of eleven, each of whom had one normal lower extremity and one involved extremity

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TABLE I

Cases with Muscle Score under Fifty-eight in Involved Extremity

	Age at Onset 0–5 years	6–10 years
Number of cases	21	3
Average muscle score	37	19
Average percentage of growth	93 1	92 4

TABLE II

Cases with Muscle Score between 58 and 115 in Involved Extremity

	Age at Onset 0–5 years	6–10 years
Number of cases	32	8
Average muscle score	85	97
Average percentage of growth	97 8	97 3

ing them into two groups, according to the muscle score in the involved extremity, each of these groups was subdivided according to age at onset In cases where the muscle power was less than 58 (Table I) and the onset under the age of six, the average percentage of growth was 93 1 When the onset was from six to ten years, inclusive, the average percentage of growth was 92 4 These groups represent only twenty-one cases and three cases, respectively, so that the figures are not conclusive, but at least for these twenty-four cases, the patients in the groups with onset from six to ten years, inclusive, had essentially the same amount of shortening or slightly more shortening than those with an earlier onset

Another analysis (Table II) was made for cases with moderate to no weakness, or a muscle score between 58 and 115 in the involved extremity In this group, there was no significant difference between the percentage of growth in cases with early or late onset For the entire group of sixty-four cases, the average percentage of growth was identical in the younger and the older patients (Table III)

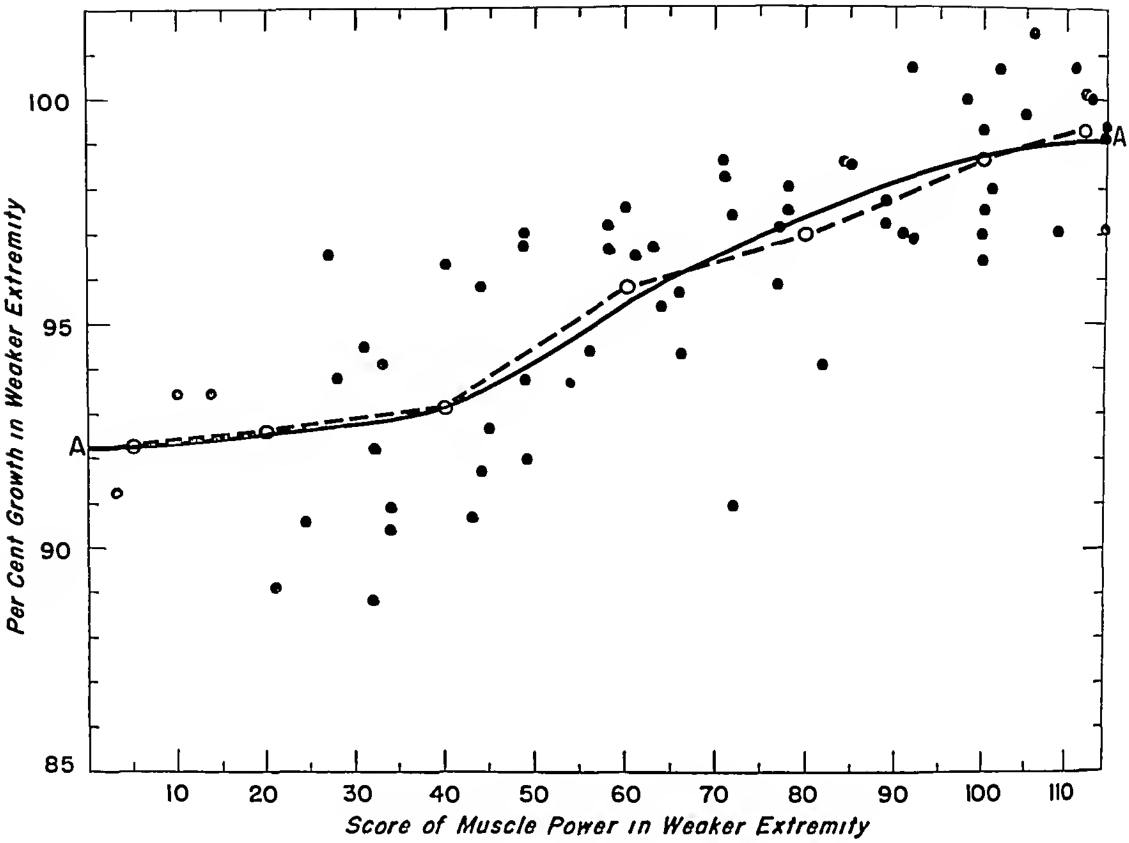
TABLE III

Cases with Muscle Score between 0 and 115 in Involved Extremity

	Age at Onset 0–5 years	6–10 years
Number of cases	53	11
Average muscle score	66	76
Average percentage of growth	95 9	95 9

After studying the patients who had one normal extremity and one involved extremity, those with bilateral involvement were analyzed In order to do this, they were divided into groups as follows The data on thirty-eight patients having a muscle-power score of 110 to 91 in one extremity and the same or a lower score in the other were plotted and a trend line was constructed (Graph II,*B*) This shows the percentage of growth attained in the weaker extremity with varying muscle-power scores Similarly, the data for twenty patients who had a muscle score of 90 to 71 in one extremity and the same or a lower score in the other extremity were plotted (Graph II *C*) Similar trend lines for the other groups were made, as shown in Graph II

To use these data clinically in the prediction of inequality of limb length, the percentage of growth shown on the charts must be transposed into centimeters of shortening In the first group of cases analyzed, the average length of the normal extremity was 86 4



GRAPH I

This graph presents sixty-four adults who had acute poliomyelitis before the age of eleven and were left with one normal extremity and one involved extremity. Each solid dot represents one case and is so placed that it records the muscle power and percentage of growth in the weaker extremity. The score of the muscle power in the weaker extremity is recorded on the abscissa, the percentage of growth in the weaker extremity is recorded on the ordinate. (Percentage of growth in the weaker extremity was found by dividing the length of the weaker extremity by the length of the stronger extremity.) The broken line with the circles shows the average relationship between percentage of growth and muscle power. Line *A* is the trend line for the entire series of data.

been drawn. The small circles connected by the broken line represent average values. Beginning at the left and proceeding to the right, the first circle represents the average percentage of growth of the cases with a muscle-power score between 0 and 10, the next circle is the average for cases with muscle power from 11 to 30, inclusive, each of the successive circles represents the averages for groups of cases with muscle power between 31 and 50, 51 and 70, 71 and 90, 91 and 110, and 111 and 115. With the average line as a guide, a trend line, *A*, was constructed.

The age at onset of poliomyelitis in these sixty-four cases varied from two months to ten years. In sixteen cases (25 per cent), the onset of poliomyelitis was in the first and second years of life, in twenty-four cases (38 per cent), the onset was in the third and fourth years, in thirteen (20 per cent), in the fifth and sixth years, in seven (11 per cent), in the seventh and eighth years, and in four (6 per cent), in the ninth, tenth, and eleventh years.

The relationship of the age at onset to inequality of limb length was considered. The premise that the earlier the onset of poliomyelitis, the greater would be the shortening, was not proved in this group of cases. If the age at onset had affected growth, those with an early onset would have had greater than the average amount of shortening and would have been below the trend line in Graph I. The average age at onset of the cases below the trend line was 3.2 years, for those above the trend line, it was practically identical, or 3.1 years.

The cases were analyzed further, to ascertain the effect of the age at onset, by divid-

TABLE I

CASES WITH MUSCLE SCORE UNDER FIFTY-EIGHT IN INVOLVED EXTREMITY

	Age at Onset 0–5 years	Age at Onset 6–10 years
Number of cases	21	3
Average muscle score	37	19
Average percentage of growth	93.1	92.4

TABLE II

CASES WITH MUSCLE SCORE BETWEEN 58 AND 115 IN INVOLVED EXTREMITY

	Age at Onset 0–5 years	Age at Onset 6–10 years
Number of cases	32	8
Average muscle score	85	97
Average percentage of growth	97.8	97.3

ing them into two groups, according to the muscle score in the involved extremity, each of these groups was subdivided according to age at onset. In cases where the muscle power was less than 58 (Table I) and the onset under the age of six, the average percentage of growth was 93.1. When the onset was from six to ten years, inclusive, the average percentage of growth was 92.4. These groups represent only twenty-one cases and three cases, respectively, so that the figures are not conclusive, but at least for these twenty-four cases, the patients in the groups with onset from six to ten years, inclusive, had essentially the same amount of shortening or slightly more shortening than those with an earlier onset.

Another analysis (Table II) was made for cases with moderate to no weakness, or a muscle score between 58 and 115 in the involved extremity. In this group, there was no significant difference between the percentage of growth in cases with early or late onset. For the entire group of sixty-four cases, the average percentage of growth was identical in the younger and the older patients (Table III).

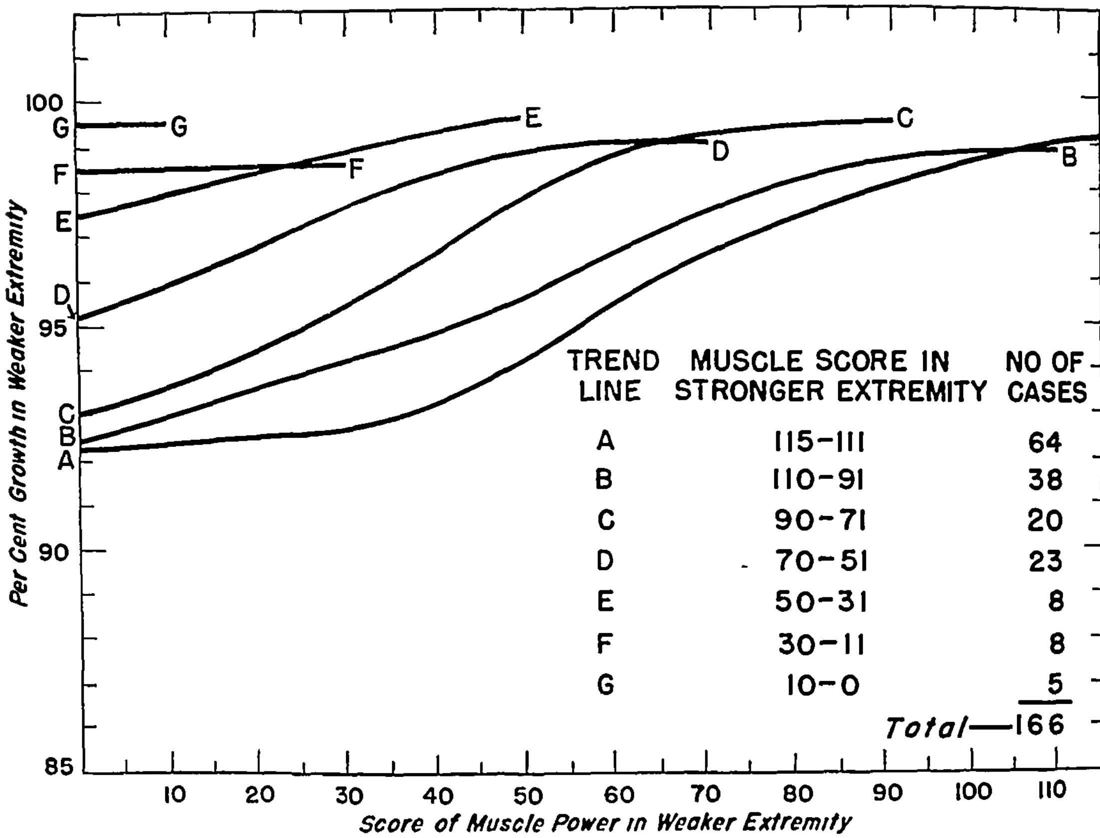
TABLE III

CASES WITH MUSCLE SCORE BETWEEN 0 AND 115 IN INVOLVED EXTREMITY

	Age at Onset 0–5 years	Age at Onset 6–10 years
Number of cases	53	11
Average muscle score	66	76
Average percentage of growth	95.9	95.9

After studying the patients who had one normal extremity and one involved extremity, those with bilateral involvement were analyzed. In order to do this, they were divided into groups as follows. The data on thirty-eight patients having a muscle-power score of 110 to 91 in one extremity and the same or a lower score in the other were plotted and a trend line was constructed (Graph II,*B*). This shows the percentage of growth attained in the weaker extremity with varying muscle-power scores. Similarly, the data for twenty patients who had a muscle score of 90 to 71 in one extremity and the same or a lower score in the other extremity were plotted (Graph II,*C*). Similar trend lines for the other groups were made, as shown in Graph II.

To use these data clinically in the prediction of inequality of limb length, the percentage of growth shown on the charts must be transposed into centimeters of shortening. In the first group of cases analyzed, the average length of the normal extremity was 86.4



GRAPH II

This graph presents 166 adults who had poliomyelitis before the age of eleven, they have varying amounts of residual muscle power in the lower extremities Trend line A is for patients who had a muscle score in the stronger or normal extremity of 115 to 111 and a score in the other extremity of 0 to 115 Trend line *B* is for patients who had a muscle power of 110 to 91 in one extremity and the same or a lower score in the other extremity It shows the percentage of growth attained in the weaker extremity with varying muscle-power scores Patients who had a muscle score of 90 to 71 in one extremity and the same or a lower score in the other extremity are represented by line *C* Other groups are shown as indicated

centimeters (34 inches) If this average length is multiplied by the percentage of growth, the product is the length of the involved extremity By subtracting the calculated length of the involved extremity from the length of the average normal extremity, the amount of shortening is obtained (Table IV) Also included in Table IV is the estimated shortening for an extremity 76 2 centimeters long and for an extremity 96 5 centimeters long (four inches shorter and four inches longer than the average length) If the percentage of growth is 99, the shortening in the short, average, and long extremities would be 0 8, 0 9 and 1 0 centimeters, respectively The variation of these amounts from the shortening in the extremity of average length is as small as or smaller than the margin of error in clinical measurements With 94 per cent growth, the shortening of the short, average, and long extremities would be 4 6, 5 2, and 5 8 centimeters Again the variation from the extremity of average length is small (0 6 centimeters), and is of the same order or smaller than the

TABLE IV

ESTIMATED SHORTENING IN EXTREMITIES OF VARIOUS LENGTHS

Length of Extremity	Percentage of Growth 99	94	88
Short (76 2 centimeters or 30 inches)	0 8 cm	4 6 cm	9 1 cm
Average (86 4 centimeters or 34 inches)	0 9 cm	5 2 cm	10 4 cm
Long (96 5 centimeters or 38 inches)	1 0 cm	5 8 cm	11 6 cm

TABLE V

Sixty-four Patients with One Normal Lower Extremity
(Muscle Score of 115 to 111)

Muscle Power in Weaker Extremity	Amount of Shortening in Weaker Extremity (*Centimeters*)
115–111	0.8
110–91	1.2
90–71	2.3
70–51	4.0
50–31	5.8
30–11	6.4
10–0	6.7
One standard deviation	±1.5

variation in clinical measurements. When the percentage of growth is 88, the variation of shortening is somewhat larger. It is evident that there is usually insufficient variation of shortening to necessitate making corrections for long and short extremities. Therefore, all later calculations were based on extremities of average length.

By using this method for calculating shortening, the percentage of growth represented by the trend line in Graph I can be converted to centimeters of shortening for an extremity of average length (Table V). The standard deviation for these cases, in terms of shortening, was 1.5 centimeters.

TABLE VI

SHORTENING

OF LOWER EXTREMITIES AFFECTED BY POLIOMYELITIS

MUSCLE POWER LEFT EXTREMITY	MUSCLE POWER RIGHT EXTREMITY 115-111	110-91	90-71	70-51	50-31	30-11	10-0
115-111	CM 0.8	CM. 1.2	CM. 2.3	CM. 4.0	CM. 5.8	CM. 6.4	CM. 6.7
110-91	1.2	1.0	1.6	2.9	4.5	5.5	6.3
90-71	2.3	1.6	0.5	1.0	3.0	4.8	5.8
70-51	4.0	2.9	1.0	0.8	1.4	2.9	3.8
50-31	5.8	4.5	3.0	1.4	0.3	1.4	2.0
30-11	6.4	5.5	4.8	2.9	1.4	1.3	1.3
10-0	6.7	6.3	5.8	3.8	2.0	1.3	0.4
	± 1.5 CM. ONE STANDARD DEVIATION						

STINCHFIELD, BARR AND REIDY, MASSACHUSETTS GENERAL HOSPITAL, BOSTON, MASS. TENTATIVE, 1948

In a similar fashion, the calculated shortening for an extremity of average length was determined for the other groups of cases shown in Graph II (Table VI). This table represents the statistical analysis of 166 cases of poliomyelitis with onset before the age of eleven. The calculated average shortening occurring with varying amounts of muscle weakness is recorded. The standard deviation for the first column of sixty-four cases having one normal extremity (vertical column 115–111) was 1.5 centimeters. The standard deviation for the other groups of cases did not exceed this amount.

A means was sought for applying this information to the prediction of expected shortening. We had found early in the study that, after the acute stage of poliomyelitis, the muscle power gradually improved for eighteen to twenty-four months. Following this period, there was usually little change in the muscle pattern. It appeared, therefore, that prediction of shortening could be based on muscle examinations done two or more years after the onset of the disease.

Although the prediction of growth or lack of growth is subject to much individual variation, it was anticipated that clinical application could be made of the relationship between muscle power and shortening found in this study. To predict the amount of shortening, a muscle examination done by the Lovett method should have been made two or more years after the onset of the disease. After the muscle gradings of normal, good, fair, poor, trace, and zero have been converted to the numerical gradings of 5, 4, 3, 2, 1, and 0 respectively, these gradings are totaled for the right extremity and for the left extremity. The result will give a muscle-power score for each extremity of between 0 and 115. By examining Table VI under the proper column for scoring of the right and of the left extremity, the amount of expected shortening is found. The standard deviation for this table is 1.5 centimeters. Only in cases of poliomyelitis occurring before the age of eleven should this chart be used, as the cessation of growth occurs at some variable time after this age.

SUMMARY

Of 166 adults in whom poliomyelitis developed before the age of eleven, varying degrees of muscle power and shortening were present in the lower extremities. There was no specific relationship between the age of onset and the amount of discrepancy in limb length. There was, however, a definite relationship between the relative muscle strength in the two extremities and the discrepancy in limb length. These data may be utilized clinically in predicting the amount of shortening that will occur in a patient having poliomyelitis before the age of eleven.

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DISCUSSION

DR. WILLIAM T. GREEN, BOSTON, MASSACHUSETTS: The problem which Dr. Stinchfield, Dr. Reidy, and Dr. Barr have approached we have found to be a most difficult one, and I am sympathetic with their difficulties and the work involved. For certain of their deductions, they have been forced to use groups of patients which were too few in number for statistical deduction. For example, in comparing the growth of the affected and normal sides in those younger and those older at the time of onset, they have only three patients between the ages of six and eleven in the group with extensive paralysis and only eight patients at this age with lesser degrees of paralysis. This will not allow statistical representation that the effect upon growth is the same, whether a patient is affected by poliomyelitis at an earlier or later age under eleven years. These and other weaknesses in certain portions of this paper arise from the character of the material which had to be used and from the nature of the problem. Moreover, this does not detract from the finding that, in their patients under eleven years of age, the shortening at maturity corresponds with the degree of paralysis, or that it was independent of the age at onset.

If one were hazarding a guess as to what would occur, without any information, this would seem most unlikely. This really means that a child who has poliomyelitis at ten years of age has a much greater degree

of growth inhibition during the growing period than does a child who has the disease at two years of age. To carry this further, in 20 per cent. of our cases in girls, no longitudinal growth occurred after the age of thirteen years. This would mean that in the extreme case of a girl in whom the disease developed just before eleven years of age, a phenomenal inhibition of growth—in certain instances amounting to 100 per cent. or more—would have to occur immediately after the onset.

On the surface, it would seem more logical to expect that a constant coefficient of growth inhibition would exist following poliomyelitis,—that is, that the inherent effects of the disease on the extremity would inhibit growth by a certain percentage each year, and that the shortening would be a product of the amount the patient grows and the percentage of inhibition. In fact, however, this constant coefficient has not occurred in their cases or in ours. Furthermore, our cases show to some degree the tendency which the authors have described, although not to the extent that theirs do. In fact, our cases follow much more closely a constant coefficient of growth inhibition each year, specific to the individual case, than they do a fixed amount which is independent of the age at onset.

These tendencies were demonstrated by distributing fifty of our cases in which infantile paralysis had occurred before the patient was ten years of age, and comparing the amount of shortening which occurred at maturity with the shortening that was predicted by two methods. In one instance, the prediction followed the method of the authors in which the duration of the disease was ignored. In the other, the distribution considered the amount of paralysis and the years of growth remaining after onset. In reality, the latter method represents a prediction based upon an assumed constant percentage of inhibition of growth each year after onset until growth is completed. The prediction was very much better by the second method, although in thirteen of the fifty cases the prediction varied from the real shortening by 1.5 centimeters or more. However, even those outside of the range were quite close to the 1.5 centimeters of variation. By the method proposed by the authors, twenty-two of the fifty missed the prediction by more than 1.5 centimeters, and marked deviation from the prediction existed in many of these. One may conclude that neither method is very dependable.

One of the chief reasons for this, I believe, is that growth is affected to a variable degree by the disease, depending upon the duration after onset. This is illustrated by a survey of our cases. Two hundred and fifty-seven cases in which one lower extremity was affected by variable degrees of paralysis and the other was normal were analyzed as to the annual increments of inhibited growth. These were subdivided into four divisions, based upon the degree of power in residual muscles. In all of the groups, it was found that the average maximum inhibition occurred from the second to the fifth year after the onset of the disease,—that is, there was less inhibition prior to the second year and less inhibition each year after the fifth year following onset.

To carry this point further, seventeen patients who had six years to grow at the time of onset of the disease were studied as to the discrepancy which occurred each year. These patients had unilateral involvement of the lower extremities, the residual muscle power in the affected extremity was sixty-four. It may be seen (Slide) that these patients had sufficient time to go through their years of maximal yearly inhibition, despite the relatively short period of growth after the disease. These cases, therefore, would tend to demonstrate the phenomenon which the authors have described, but it is only relative. If the patients had a longer period to grow, there would be still more discrepancy. However, the inhibition of growth in other years would not be so much as in the critical period of two to five years after onset. In attempting to predict the amount of discrepancy, there has been a high correlation in our cases with the amount of paralysis, but there is great variation.

There are many factors involved which cannot be discussed. All in all, this is a difficult problem, and we are indebted to the authors for their contribution toward its understanding.

We are very much indebted to Dr. Blount for the presentation of his experience in the use of staples to inhibit growth. In correcting discrepancies, the next best thing to being able to stimulate growth is to be able to stop it for an interval and yet have the possibility of allowing growth to resume. It makes accuracy in prediction of growth less important than in ordinary epiphyseal arrest, although no procedure should be carried out without full consideration of the growth which is normally expected from the particular epiphysis and the anticipated effect of the procedure upon growth. Prediction tables should be consulted freely.

From the evidence, this seems to be a very good method to correct certain deformities, if used properly. It cannot be decided at this time whether it is less good or better than the Phemister type of arrest, if one wants to stop growth completely. Certainly the author has had difficulties, as witness the increasing number of staples which he is using now, the broken staples, and the multiple procedures. However, this is inherent in the development of a new method and does not necessarily condemn it. The important thing is that it gives the possibility of having growth resume. Longer observation of more cases will be necessary before we can determine how dependably growth will resume after removal of the staples.

Certainly one must consider carefully, before using staples in younger children, when it is proposed to remove them and have growth resume. Disturbing consequences may result if growth does not start again. Those of us who use this technique must observe our cases carefully, and contribute to an evaluation of the method. We will await with interest Dr. Blount's further observations. The technique has many possibilities.

Dr J Warren White, Greenville, South Carolina Although both of these papers are on the same general subject, the material is so different that one can hardly discuss them together satisfactorily The report from Dr Reidy, Dr Barr, and their associates two years ago, relative to the danger of using roentgen irradiation in arresting growth, was a valuable contribution, the present paper has added new data to the information already contributed by this group

One would naturally expect more shortening in the cases with greater involvement, but my opinion is that the amount of shortening depends more upon function than upon the empirical figure derived from the muscle-strength test Not all muscles are affected alike, and a wide variation in function is possible with this method of muscle-strength evaluation, whereas the empirical figure showing the muscle power for the entire extremity is the same For instance, if the glutaeus maximus and the quadriceps were paralyzed to a high degree, and the hamstrings and hip flexors were relatively unaffected, the final figure would be the same as if all muscles were mildly affected, yet there would be much more associated disability in the case of the seriously involved glutaeus maximus and the quadriceps

I feel that the shortening would be due to the dysfunction However, the evaluation of disability is very difficult, and a definite figure, such as that obtained in testing muscle strength, is much more satisfactory I hope we can depend upon it

I have had a good deal of difficulty in understanding this paper I had to read it several times, and I am sure that the audience has had difficulty, also The charts are a little hard to follow without study In our own cases of limb-length discrepancy we have marveled at the regularity with which shortening gradually occurs during the growth period On that basis we have apparently an increasing series, which shows that we can depend on this annual decrement We have, however, also seen that as constructive surgery is done, and as the patient can use to better effect the short limb, the decrement tends to become less and our own calculations tend to be somewhat upset Because of this, in making our calculations, we have leaned toward the conservative side In most instances there is a little more growth than we anticipated, and, if we had been conservative, the overgrowth in sixteen of our earlier cases might not have occurred In spite of the figures given in the paper, I am of the opinion that, to predict final shortening, one has to watch a patient for a year or two after the first two years of convalescence, and see what the annual decrement is From that, the final discrepancy can be figured, as seen on one of the charts in our scientific exhibit

Therefore, we feel that function, rather than paralysis, is important in the determination of final discrepancies The very fact that muscle power usually coincides with disability permits the conclusion that it may be a good criterion, if the findings continue to be consistent

Dr Blount has made a valuable contribution to our armamentarium and to the procedures which can be done,—in this instance, on the long lower extremity rather than the short one Time will tell how certain it is I am still a little skeptical, and will wait a few more years before I use staples, except in cases of genu varum or genu valgum We have used staples in a few of those cases It is still early to form a definite conclusion, but I think the method is more likely to be valuable in the conditions mentioned than as a means of effecting complete stoppage There is one difficulty associated with these staples, and that is, as Dr Blount believes, you can leave them in for only two years Leaving them in for longer than that tends to produce definite damage, which I am afraid occurs proximally on the metaphyseal side of the plate Dr Blount places the staples blindly, and yet doesn't want to have any tissue impaled This seems contradictory, as one moves the tissue overlying bone, the plate is necessarily exposed and the staples can be placed visually I think it is important to place the staples visually The procedure must be very exact, even from the roentgenogram. one cannot tell definitely just where the staples are We are all wondering about the ability of the plate to resume function after it has been stapled for a couple of years Tremendous force is exerted by these growing cells, and it is surprising that even three staples are strong enough We shall look forward to a subsequent report on this method of arresting growth

Dr Joseph S Barr, Boston, Massachusetts (closing) Everyone who has had to deal with the problems of poliomyelitis in the late stage has felt the need for some method of predicting the amount of discrepancy in limb length which could be expected when the patient reached adult life Up to the present time there has been no method available The one which we propose has obvious defects and cannot be expected to be accurate in all cases It should be regarded as a first attempt We will all look forward to the development of more accurate methods Nevertheless, this method has the virtue of simplicity All that is necessary is an accurate muscle examination, done in the late stage of the disease, in a child who has not reached the age of ten or eleven It requires about five minutes to assign a numerical value to the muscle power in each extremity, to consult the prediction table, and to obtain a figure which in 70 per cent of our cases has been accurate within an error of less than 1 5 centimeters

Since our paper was prepared, we have had the opportunity to check the accuracy of the table in ninety-seven additional cases In seventy-one (or 73 per cent) of the cases, the actual discrepancy in limb length fell within the predicted range Twenty-seven per cent were outside the predicted range

We realize that relative muscle power in the two extremities is by no means the only factor involved, but it is certainly a major one At the present time no means are available by which we can measure, in

(*Continued on page 500*)

EFFECT OF DIATHERMY (SHORT WAVE AND MICROWAVE) ON BONE GROWTH IN THE ALBINO RAT *†

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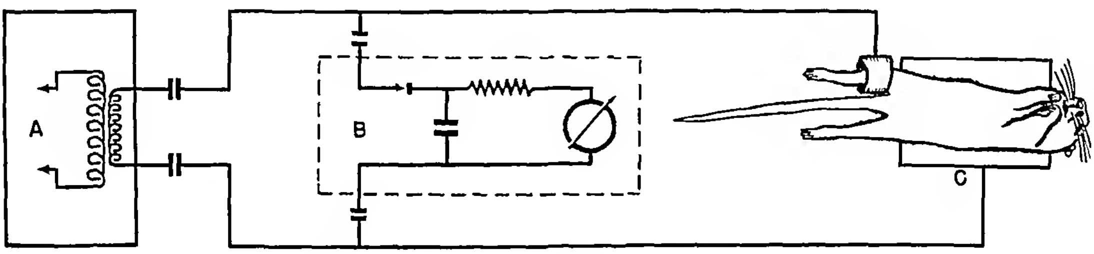
Physical agents capable of affecting bone growth are of interest to the clinician dealing with growth in general, as well as to the orthopaedic surgeon investigating mechanisms of epiphyseal arrest. The susceptibility of the growing epiphysis to roentgen radiation, demonstrated by recent workers[1-6], raises the question of a similar effect of high-frequency electrical currents. The widespread use of diathermy in medical practice today emphasizes the need for more information concerning its physiological effects, as well as its potential dangers. This paper describes a set of observations concerning the effect of diathermy, applied to the region of the knee joint in the growing albino rat. Single exposures of either condenser field, short wave (8-meter wave length) or microwave (11-centimeter wave length), were employed in approximately fifty animals. The contralateral knee served as a control. Appropriate animals were sacrificed and examined at varying intervals following exposure for changes in bone length, soft-tissue reaction, and in the roentgenographic and microscopic appearance of the treated epiphysis.

METHOD

1. *Short-Wave Diathermy* (8-meter wave length)

Forty 100-gram albino rats were anaesthetized by intraperitoneal nembutal. A small cuff electrode, 2 centimeters in diameter and 1.5 centimeters wide, suitably insulated with cotton wadding, 0.5 centimeter in thickness, was placed over the right knee joint. The animal was held in place on its back over an insulated indifferent pad electrode, 10 by 6



A Clinical Short Wave Generator B Voltmeter Circuit C 100 Gram Albino Rat

FIG. 1

Method of applying short-wave diathermy to the region of the knee

centimeters. The electrodes were capacitatively coupled to the spaced plates in the patient's circuit of a standard clinical short-wave diathermy machine. Dosage was regulated by varying the resonance in the patient's circuit. Relative power output in the animal circuit was measured by means of a shielded milliammeter with a fixed shunt resistor, and rectified capacitatively, coupled to the electrode leads (Fig. 1). Meter readings of ten, seven, five, three, and two indicated the relative voltage in the animal circuit in

* Read before the Orthopaedic Section of the American Medical Association, Chicago, Illinois, June 24, 1948.

† This work was aided by a grant from the National Foundation for Infantile Paralysis, Inc.

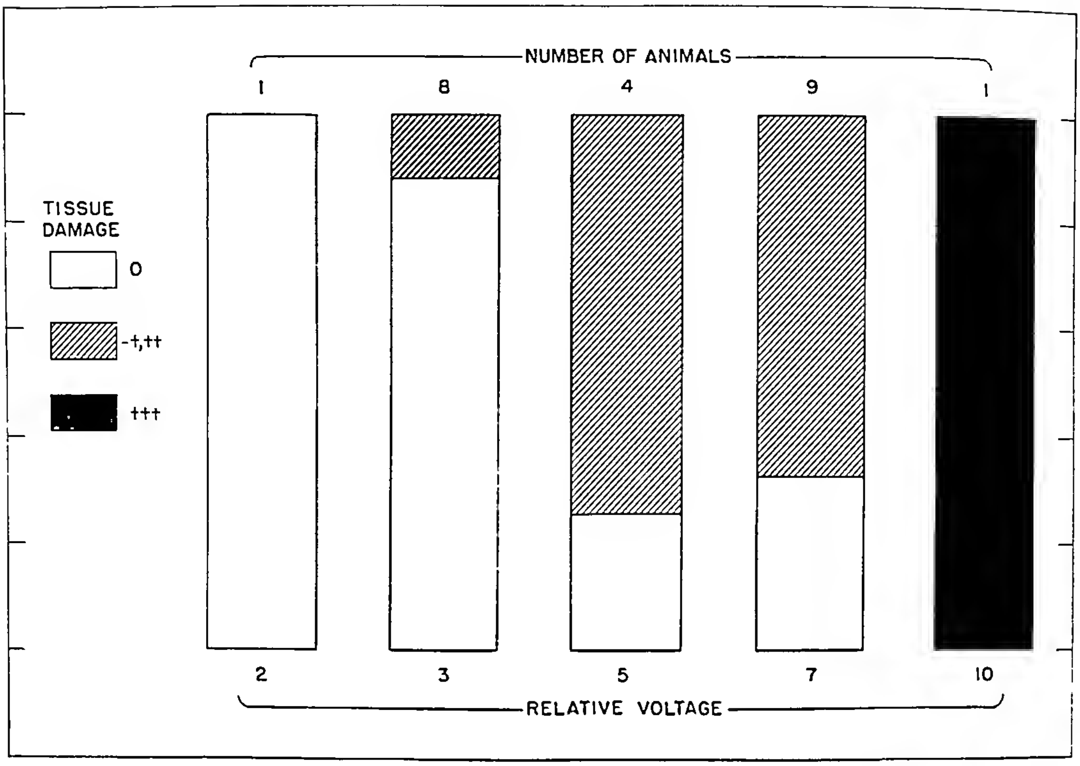


FIG. 2

Relation of short-wave diathermy to soft-tissue reaction

various experiments. Duration of exposure was either five, ten, or fifteen minute
The extremity was examined immediately after treatment and graded according t
the following scale, based on soft-tissue reaction:

0 Extremity warm to touch as compared to the control, but no other gro difference noted.

\+ Slight swelling present in surrounding soft tissues and slight increase i resistance to passive motion, either alone or in combination.

++ Marked swelling present in surrounding soft tissues and marked increase i resistance to passive motion of the treated joint, either alone or in com bination.

+++ Ulceration or evidence of gross tissue destruction.

The animals were observed at regular intervals following exposure, and secondar changes, such as atrophy, limp, or foot drag, were noted. At two, four, six, eight, ten twelve, and thirty-six weeks after treatment, selected animals were sacrificed. Examinatio included roentgenograms and gross descriptions of the bone and soft tissues. Microscopi sections were taken of the distal portion of the femur and the proximal portion of th tibia, including the epiphyseal plate in most instances, of both the treated and contro limbs.

2. *Microwave Diathermy* (11-centimeter wave length)

Animals under intraperitoneal nembutal anaesthesia were exposed to microwave radiation emitted from a microtherm, a parabolic reflector being used. The animal wa placed under a metal shield except for the region of the right knee, thus protecting the rest of the animal from the microwave radiation. In different experiments the source of the radiation was placed at varying distances from the treated limb, ranging from direct contact to 4 centimeters. The power output of the machine was set at either 25 per cent, 50 per cent, or 75 per cent of the 130-watt total capacity of the instrument. Duration of treatment was ten minutes in all cases, except for one animal which was

TABLE I

SHORT-WAVE DIATHERMY

Rat No	Voltage	Treatment (*Minutes*)	Clinical Results	Sacrifice (*Weeks after Treatment*)	Condition at Time of Sacrifice	Autopsy and Microscopic Findings
31	10	5	+++	2	Large ulcer, gangrene of foot	
39	7	5	++	2	Limp, ulcer	Purulent arthritis, *Staph albus*, alpha-hemolytic Strep , marked degenerative changes
40	7	5	++	4	Limp, ulcer	Thigh atrophy, one-third normal, thickening of joint capsule, limitation of joint motion, marked destruction of epiphysis
37	7	5	+	2	Limp	Muscle atrophy, limitation in joint motion, cystic changes in epiphyseal plate, marrow fibrosis of metaphysis and epiphysis
38	7	5	+	4	Normal	Slight scar over tibia, epiphysis grossly abnormal, narrowed, and partially destroyed
33	7	5	+	4	Normal	Slight scar, ? microscopic changes in epiphyseal plate
34	7	5	+	36	Normal	No changes noted
32	7	5	0	2	Normal	No gross changes, ? cystic degeneration of epiphyseal cartilage
36	7	5	0	6	Normal	No changes noted
35	7	5	0	12	Normal	No gross changes
11	5	5	++	10	Scar limp	Muscle atrophy, epiphysis grossly abnormal, almost obliterated, hyperplasia of synovial membrane
15	5	5	+	6	Limp, ulcer	Scar adherent to fascia below and lateral to knee, quadriceps atrophy, epiphyseal plate ossified and narrow, synovitis
12	5	5	+	36	Limp, scar	Gross deformity right femur 2 8 cm , control 3 5 cm , limited extension of right knee
14	5	5	0	36	Normal	No changes noted
13	5	3	+++	2	Ulceration, gangrene of foot	Spontaneous amputation of leg
29	3	15	++		Died 10 days after treatment	Deep ulceration of thigh
26	3	15	+	6	Scar, ? limp	No gross changes, knee cut with diminished resistance, minor changes in epiphyseal cartilage
27	3	15	+	10	Normal	No gross changes
28	3	15	0	36	Normal	No changes noted
30	3	15	0	36	Normal	No gross changes
16	3	5	+	36	Normal	No gross changes
19	3	5	0	3	Normal	No gross changes
18	3	5	0	4	Normal	No gross changes
20	3	5	0	6	Normal	No changes noted
17, 21, 23, 24, 25	3	5	0	36	Normal	No changes noted

TABLE II

MICROWAVE DIATHERMY

Rat No.	Relative Wattage*	Treatment (*Minutes*)	Distance from Reflector (*Centimeters*)	Clinical Result	Sacrifice (*Weeks after Treatment*)	Condition at Time of Sacrifice	Autopsy, Microscopic, and X-Ray Findings
41	75	10	Contact	Animal did not survive			
42	25	10	Contact	+++	34	Flail extremity	Complete absorption of lower portion of femur and upper portion of tibia, with skin pedicle connecting foot to trunk (see text and Figs. 9-A and 9-B). Cross section of pedicle shows nerve and skin normal, muscle bundle atrophied, no evidence of bone
43	25	10	1	++	4	Scar, limp	Muscle atrophy, increased periarticular yellow fibrous tissue, marked synovial hyperplasia. Complete absence of epiphyseal cartilage in distal portion of femur
44	25	10	2	+	8	Muscle atrophy, no scar, slight limp	Right tibia 31 m.m., left tibia 34 m.m. Right femur 24 m.m., left femur 29 m.m. (control). Destruction of central portion of femoral and tibial epiphyseal cartilage
45	50	10	1	++	2	Limp, ulceration	Muscle atrophy, no gross bone changes. One end of epiphysis destroyed, but epiphyseal plate not injured
46	25	40	4	0	Died †		
47	50	10	4	0	34	Normal	No changes noted
48	75	10	4	0	34	Normal	No changes noted
49	25	10	2	0	2	Normal	No changes noted
50	25	10	1.5	0	34	Normal	No changes noted

* Percentage of 130-watt total output.
† This animal died, of unknown cause, five weeks after treatment.

exposed at low intensity for forty minutes Following the treatment, the animals were graded as to soft-tissue reactions and examined as described

RESULTS

The results (Tables I and II) can be summarized under the following headings (1) relation of diathermy dosage to soft-tissue reaction, (2) relation of diathermy to bone growth, and (3) pathological changes in bone and soft tissues following exposure to diathermy

1 *Relation of Diathermy Dosage to Soft-Tissue Reaction*

In these experiments the relative voltage employed in the exposure is compared with the resulting soft-tissue reactions The results of short-wave diathermy are shown in Figure 2

Although there is a general correlation between the relative dose and the degree of tissue injury, sufficient variation in response exists to make accurate and predictable dosage impossible under the existing conditions It is well known that variation in the distribution of the electric field will result from minor differences in the geometric orientation between the dielectric and the electrodes[3] It is conceivable, therefore, that, despite the same relative voltage readings between the electrodes in different experiments, minor variations in the application of the cuff electrode or conformation of the extremity would alter the distribution of the electric field sufficiently to account for the differences in tissue reaction

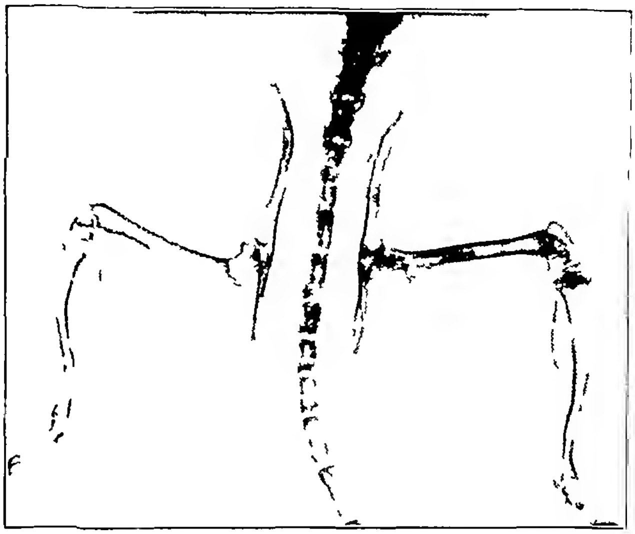


Fig 3

Roentgenogram of rat (No 12), thirty-six weeks after short-wave diathermy to right knee (five-minute treatment at relative voltage of five), showing obliteration of joint space, atrophy of epiphysis, and shortening of femur (2 8 centimeters, control 3 5 centimeters) Note also shortening of tibia, atrophy of fibula, and narrowing of tibial epiphyseal plate

With microwave radiation, similar difficulties arise in the accurate measurement of dosage In general, the dose can be varied by changing the power output of the machine, the distance of the extremity from the source of radiation, and the duration of the exposure In the experiments described, the dose was varied in such a manner as to produce all grades of tissue reaction from mild warmth to the touch, with no objective changes (Grade 0), to marked evidence of tissue destruction (Grade +++) As would be expected, there was more marked tissue reaction with higher power output and shorter distances from the source of emission Because the field strength of the microwaves diminishes as the square of the distance from the source, and since the distances used in the experiments were comparatively small, exact dosage was not possible The field distribution of the microwaves is unidirectional

In view of the difficulties in quantitatively estimating precise dosage and distribution of energy in any individual experiment, it was considered more reliable to correlate bone-growth disturbance with the soft-tissue response immediately after exposure to diathermy

2 *Relation of Diathermy to Bone Growth*

In animals where no soft-tissue changes—swelling, muscle spasm, ulceration, et cetera—were produced following diathermy treatment, no subsequent changes were observed in bone growth, either grossly or by microscopic examination In nineteen animals

TABLE III

RELATION OF SOFT-TISSUE CHANGES FOLLOWING SINGLE EXPOSURE TO SHORT WAVE OR MICROWAVE AND SUBSEQUENT EFFECT ON BONE GROWTH

Grade of Soft-Tissue Reaction	Number of Animals	
	No Effect on Bone Growth	Disturbance of Bone Growth
0	19	—
+ or ++	6	9
+++	—	3

graded 0 following a single exposure to either short-wave or microwave diathermy, the treated extremity continued to grow normally, as evidenced by roentgenograms, measurement of the femur at autopsy, and microscopic examination of the epiphysis Five animals with mild swelling and muscle spasm (Grade +) and one animal with marked soft-tissue swelling (Grade ++) also showed normal growth The remaining twelve animals with disturbance in bone growth had soft-tissue changes (Table III)

3 *Pathological Changes in Bone and Soft Tissue Following Diathermy*

As stated, pathological changes in the bone were found only in those animals receiving sufficiently large doses of diathermy to cause soft-tissue injury In these case immediately following the treatment, varying degrees of soft-tissue swelling and muscle spasm were observed, as demonstrated by increased resistance to passive motion of the knee joint In more severe cases, this was followed within twenty-four to forty-eight hours by ulceration and necrosis of the skin and soft tissues Healing was slow and varied with the extent of the burn In a few of the most severe cases, gangrene was followed by spontaneous amputation of the leg

The subsequent disturbances in bone growth following exposure to short-wave diathermy did not always parallel the degree of soft-tissue change In several animals (Nos 16, 34, and 35), moderate soft-tissue changes following treatment failed to be accompanied by subsequent disturbance in bone growth, as evidenced by roentgenographic or microscopic study of the epiphysis In another group, however, with comparable immediate soft tissue changes following treatment (Nos 12, 15, 37, and 38), considerable impairment in bone growth became apparent in later roentgenographic and pathological studies (Fig 3) In general, the roentgenographic findings paralleled the gross and microscopic changes

Many of the pathological changes observed microscopically were not unlike the changes observed after epiphyseal irradiation by Gall, Lingley, and Hilcken (An excellent description of the normal histology of the epiphysis of the albino rat may be found in their paper) The earliest changes consisted in swelling of the cartilage cells of the epiphyseal plate with fibrillation of the matrix, followed by cyst formation in a few of the cases (Fig 4 and 5) The epiphyseal plate became narrow, irregular, and distorted, and in some animals there was complete destruction of a portion of it In the cases with severe damage, the epiphysis itself was shrunken and distorted, and the marrow was fibrotic (Fig 6) In a few cases the articular cartilage showed degeneration and there was hyperplasia of the synovial membrane The hyperplasia was more marked in the animals treated with microwave diathermy

In the microwave experiments, no disturbance in bone growth was observed in any animal which did not show obvious soft-tissue change immediately after treatment Of the ten animals used, one died immediately because the dose was too large, five apparently received too small dosage to produce any clinical or anatomical change, one (No 45) showed

Fig 4

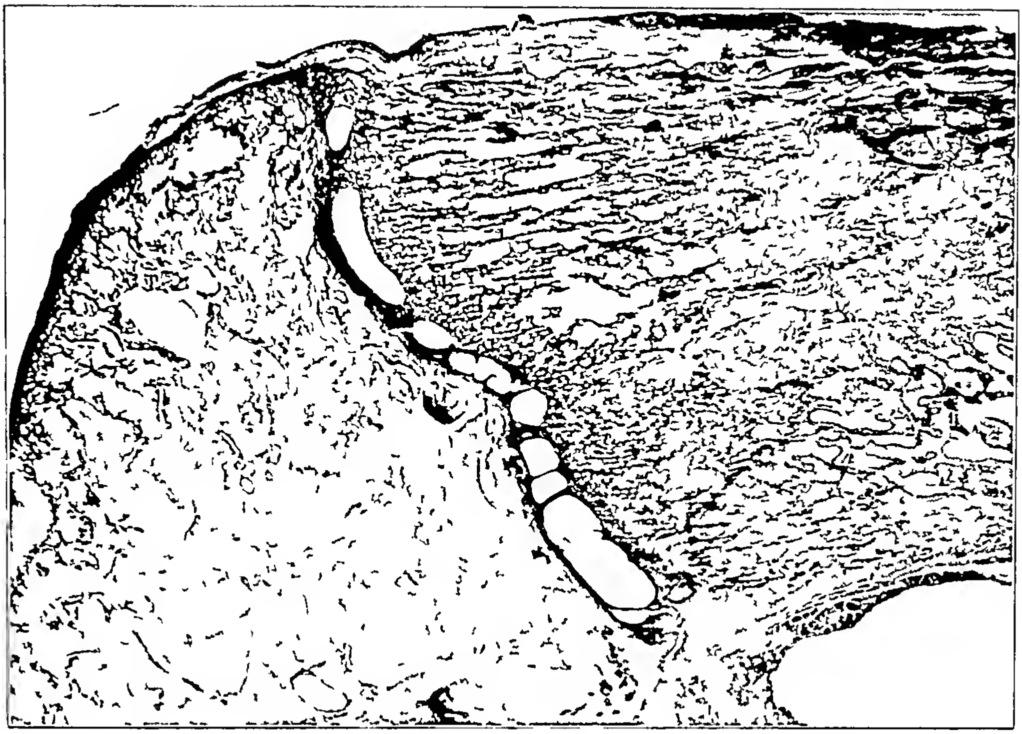


Fig 5

Fig 4 Photomicrograph ($\times$ 30) of lower end of femur of a rat with normal epiphysis, epiphyseal plate, and diaphysis

Fig 5 Photomicrograph ($\times$ 30) of lower end of femur of a rat (No 37), two weeks after short-wave diathermy, showing cystic changes in the epiphyseal plate and marrow fibrosis of epiphysis and metaphysis (Compare with Fig 4)

destruction of one side of the epiphysis and articular cartilage, but the epiphyseal plate was not injured In another animal (No 44), following exposure to microwaves, a moderate degree of local swelling appeared, which persisted for several days without obvious ulceration of the skin In spite of this mild soft-tissue reaction, there were definite bone changes, resulting in shortening of the femur during subsequent growth (Figs 7-A and 7-B) Microscopic examination in this animal showed destruction of the central portion of both femoral and tibial epiphyseal plates, as well as a portion of the femoral epiphysis and articular cartilage (Fig 7-C) Similar changes were seen in still another animal (No 43) An additional finding here was the extensive synovial hyperplasia, almost neoplastic in appearance (Fig 8)

The one animal (No 42) that survived a large microwave dose and was sacrificed at thirty-four weeks showed a bizarre result Immediately after exposure to microwave there was considerable swelling, followed in forty-eight hours by ulceration of the superficial tissues Healing was slow and was followed by complete absorption of the distal portion of the femur and the proximal portion of the tibia (Figs 9-A and 9-B) The resulting flail foot was connected to the trunk by a pedicle of skin and connective tissues The circulation, bone structure, and sensation to pin prick, as evidenced by the animal's response, were apparently unimpaired in the flail foot * A cross section of the pedicle (Fig 9-C) shows complete absence of the bone The skin surface on one side is normal, still containing the skin appendages, while that on the other side has apparently regenerated following the ulceration All the muscles are atrophic and the nerves are still present

Fig 6

Photomicrograph (× 30) of lower end of femur of a rat (No 38), four weeks after short-wave diathermy, showing marked distortion and fibrillar degeneration of the epiphyseal plate, marrow fibrosis, contraction of epiphysis, and degeneration of the articular cartilage

DISCUSSION

A review of the literature provides very little information concerning the effect of diathermy on bone growth In 1932, Nové-Josserand reported deformity of the calcaneus and epiphyseal arrest of the distal portion of the tibia in an eight-year-old girl, who, when she was only five months of age, had had a diathermy burn in the region of the heel This was accompanied by 6 centimeters of shortening Nové-Josserand stated that the calcaneal lesion, which corresponded to the cutaneous scar, resembled that which one would see in any deep burn of the heel of a child What was remarkable was that the bony lesion also produced an important effect on

* Similar deformities were produced with microwave radiation in another group of experiments, detail of the pathogenesis will be reported later

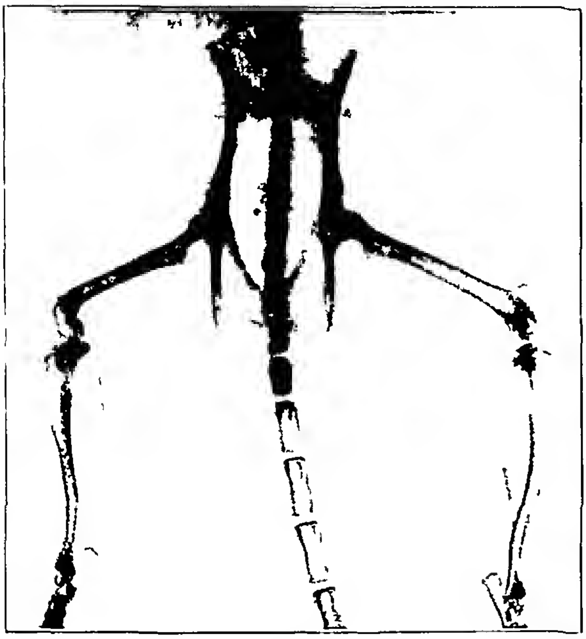


FIG. 7-A

FIG. 7-B

Fig. 7-A. Roentgenogram of rat (No. 44), eight weeks after microwave diathermy, showing destruction of femoral and tibial epiphyses and atrophy of patella. Note shortening of femur (2.4 centimeters as compared with the control measurement of 2.9 centimeters) and tibia (3.1 centimeters as compared with the control measurement of 3.4 centimeters). The tibial epiphyseal plate is narrowed.
Fig. 7-B. Photograph of lower extremities of same rat, showing shortening of bones.

the talus and the lower end of the tibia, whereas the skin at this level remained absolutely intact. Although not mentioned by the author, we can assume that the instrument responsible for the burn was of the conventional long-wave variety (approximately 100-meter wave length), in use before the present era of short-wave machines.

A personal communication * affords another instance of disturbance in bone growth presumably related to a diathermy burn. A five-month-old South American girl was stricken with poliomyelitis, with marked involvement of both lower extremities. Thirteen days after the onset of the disease, the child was treated with short-wave diathermy. An electrode was placed on the right ankle and another over the back. After twenty-five minutes of treatment she had the symptoms of heat stroke, accompanied by cardiac and respiratory collapse and convulsions. A severe burn developed in the region of the right knee, requiring over two months to heal. Roentgenograms taken from six months to three years later showed destruction of the distal femoral and proximal tibial epiphyses (Fig. 10). This was associated with considerable scar tissue and contractures in the region of the knee, which were subsequently removed surgically. The orthopaedic surgeon stated: "From the history of the use of short-wave diathermy, one is forced to the conclusion that the epiphyseal lesion is due to the deep heat induced by the short-wave diathermy apparatus. In my opinion this lesion is not due to any type of disease, and I have never seen the condition in any case of poliomyelitis. This child now has one and one-half inches of shortening due to this lesion and the shortening will progress. . . . One can suspect that there will probably be at least six inches of shortening when the child arrives at adult life."

Aside from the two examples mentioned, no instances have come to the authors' attention in which this serious sequela to diathermy burns has been reported.

In 1934, Weinberg and Ward reported the experimental observation of increased vascularization and bone repair in bone defects in dogs, subjected to daily treatment with conventional diathermy. They reported higher temperatures in the bone than in the

* The authors are indebted to Frank R. Ober, M.D., for permission to publish a report of this patient.

Fig 7-C

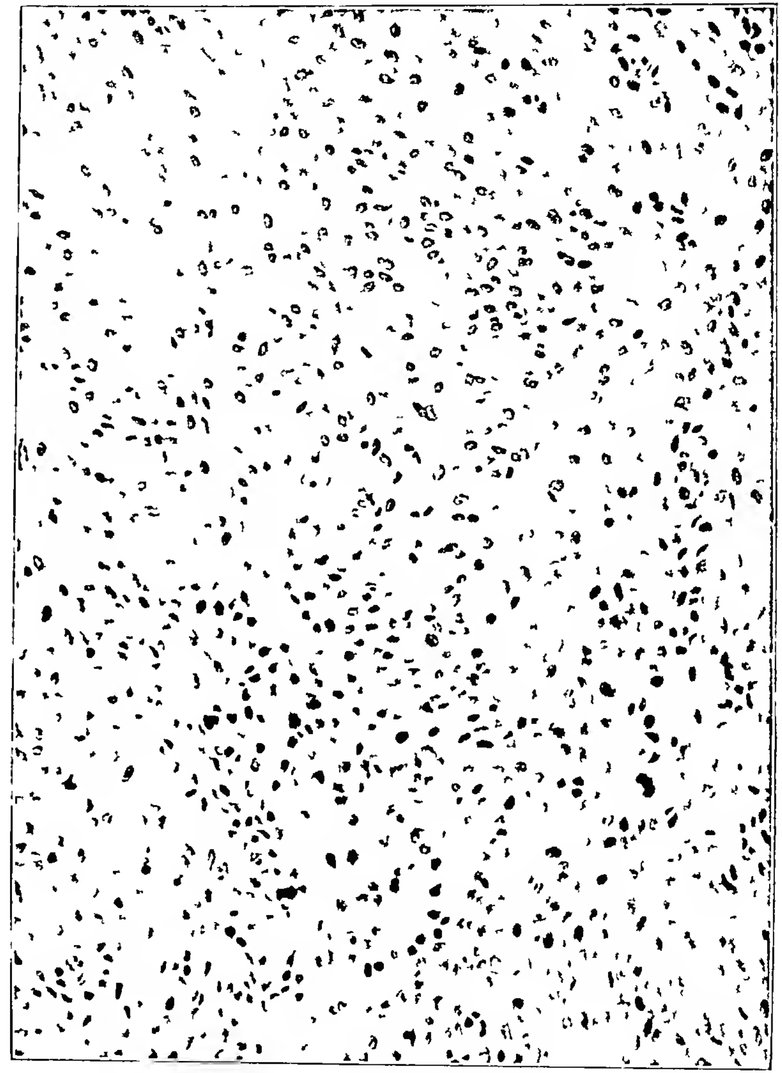


Fig 8

Fig 7-C Photomicrograph (× 30) of lower portion of femur, showing destruction of epiphysis epiphyseal plate, and articular cartilage
Fig 8 Photomicrograph (× 135) of rat No 13 shows marked synovial hyperplasia four weeks after microwave diathermy

surrounding soft tissues during the diathermy treatment. The accuracy of the temperature studies is open to question, since Weinberg and Ward implanted clinical thermometers in the tissues during the experiment.

Osborne and Coulter, on the other hand, studying the thermal effects of short-wave diathermy on bone and muscle in dogs, employed thermocouples placed in hard-rubber cannulae before and immediately after local exposure to various wave lengths and concluded that, although the temperature of the marrow may be increased more than the general body temperature, the temperature of the surrounding muscle was always higher. These authors concluded that the degree of tissue injury must always decrease from the periphery to the interior. This conclusion presupposes the same susceptibility of all types of tissue to thermal injury. It is quite possible, and even probable, that variation in vascular supply and in specific resistance to thermal injury exists in different tissues. The epiphyseal cartilage, for example, may be considerably more liable to permanent damage than the overlying skin and muscle, despite the same degree of temperature elevation.

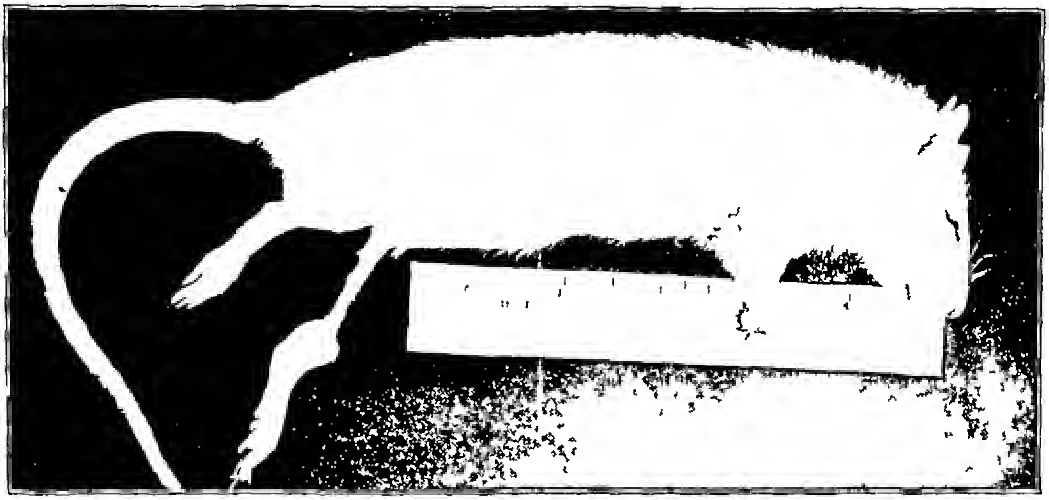


Fig. 9-A

Photograph of rat (No. 42), thirty-four weeks after a large microwave dose. Shows flail foot, resulting from dissolution of the knee and of portions of the femur, tibia, and fibula.

Fig. 9-B

Roentgenogram of same rat shows the absence of bone in the skin tube.

Fig. 9-C

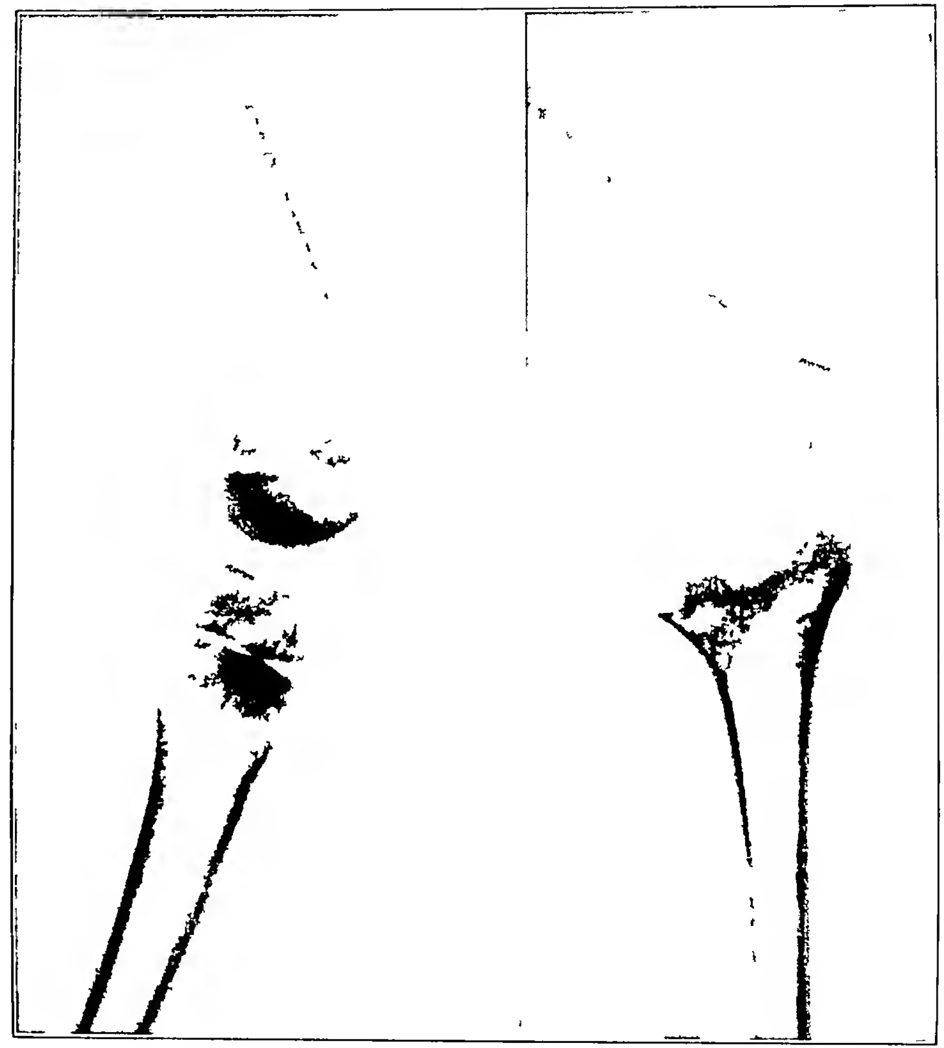


Fig. 10

Fig. 9-C. Photomicrograph (× 10) of cross section of skin tube, demonstrating absence of bone and preservation of muscle and nerves. Note absence of skin appendages in corium on side treated, in contrast to their preservation on other side.

Fig. 10. Roentgenograms of knee in an eleven-month-old child, six months after short-wave diathermy, show marked destruction of femoral and tibial epiphyses. There is marked periosteal new-bone formation at the posterior surface of the distal portion of the femur.

To those who have had clinical experience with diathermy, the difficulties of measurement of dosage are apparent. No accurate method is available at present for quantitatively determining the amount and distribution of energy absorbed by the tissues within a high-frequency electric field. In clinical usage, the dosage is varied by altering either the resonance in the patient's circuit or the output of the machine. The therapeutic dosage, however, is determined by the patient's subjective sensation of heat, rather than by any objective measurement of energy absorption. In the experiments reported in this paper, the difficulty in accurate dosage is clearly demonstrated. Despite the controlled conditions employed, it was not possible to predict the exact degree of tissue reaction to a single exposure to short-wave diathermy on the basis of the relative voltage between the two electrodes.

Under the conditions of the experiments, we can find no conclusive evidence that either short wave or microwave, when used in "clinical" dosage, has any appreciable effect on bone growth. In larger doses, however, extensive disturbance in bone growth may ensue. It was further observed that the degree of bone change with short wave, and particularly with microwave, does not always parallel the degree of skin damage or superficial-tissue damage. Perhaps the distribution of the injury following the use of more penetrating heating agents may cause thrombosis of some of the deeper vessels with resulting changes in bone growth, secondary to insufficient vascular supply. Details concerning the pathogenesis of the various lesions await further experimental studies to clarify the distribution of energy in the tissues exposed to the shorter electromagnetic radiation.

Experiments performed on the anaesthetized albino rat must be interpreted very cautiously as to clinical significance. The preliminary findings, however, suggest a warning against the careless or indiscriminate use of diathermy, particularly in the patient who has not attained full growth. The use of electromagnetic radiation as a method of elective epiphyseal arrest in cases of unequal limb length does not appear feasible.

The unusual results following severe microwave burns, characterized by extensive bone absorption, do not exclude the possible therapeutic value of this type of heating when employed in clinical dosage. On the contrary, they suggest greater penetration of these ultra-short electromagnetic waves which, under clinical supervision, may have decided therapeutic advantages. The results merely indicate the necessity for careful control of dosage and the need for further clinical and physiological studies relative to this type of radiation. It is to be hoped that further studies of the biological effects of this portion of the electromagnetic spectrum, as well as technical improvements in instrumentation, will remove some of the hazards existing at present and furnish us with a more effective therapeutic agent.

SUMMARY

1. Single exposures of either condenser field, short wave (8 meters) or microwave (11 centimeters), were applied to the region of the knee joint in approximately fifty albino rats. At varying intervals of time, appropriate animals were sacrificed and examined for changes in bone length, soft-tissue change, and roentgenographic and microscopic appearance of the treated extremity.

2. Soft-tissue injury following large dosages of diathermy showed a general correlation to the applied voltage, but sufficient variation in reaction resulted to make accurate dosage impossible under the conditions of the experiment.

3. When moderate soft-tissue injury was present immediately after exposure to either short-wave or microwave radiation, the subsequent effect on bone growth—shortening, deformity, partial or complete epiphyseal destruction, et cetera—did not always parallel the extent of the soft-tissue injury.

4. An unusual sequela to microwave burn was characterized by extensive bone absorption and resulting flail extremity.

5 In two clinical cases, extensive disturbances in bone growth resulted in children who had received burns following diathermy treatment

6 Caution should be observed in all diathermy treatments, they may be contra indicated for children

Note The authors wish to express their sincere appreciation for the generous cooperation received from Joseph S Barr, M D , of the Massachusetts General Hospital, Boston, and from Kurt S Lion, D Eng of the Massachusetts Institute of Technology, Cambridge

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DISCUSSION

Unequal Growth of the Lower Extremities

(*Continued from page 486*)

clinical cases, some of the other factors which might be of great importance, such as relative blood flow and relative function of the two extremities

Dr Walter P Blount (closing) Dr Green is right in observing that we must be cautious in stapling the epiphyses of young children Eight years is a good arbitrary figure for the lower age limit, but variations in development will influence the selection of cases The criteria are approximately the same as those for bone operations on the feet in children It is mechanically difficult to get the staples to hold in the soft bone and cartilage cap of young children Occasionally early stapling is desirable At any age, close observation at frequent intervals is necessary The younger the child, the more likelihood of extrusion of the staples This complication should be noted and corrected before angular or linear deformity results

Dr White's remarks may have injected two erroneous impressions Two years is not an absolute limit on the time that staples may be left *in situ* That is an arbitrary period, established at Dr Phemister's suggestion when stapling was begun We are now leaving staples in much longer without untoward results The safe period will be established only by continued observation, and will be reported at a later date Certainly three or four years is permissible in most cases

Dr White will find, after further experience with the method, that it is almost easier in young children to place the staples blindly than by direct vision The cartilage cap is so large and the lateral margins of the epiphyseal plate are so expanded that direct vision implies thick flap dissection The palpable contours are sufficiently accurate to be used as guides, if checked with anteroposterior and lateral roentgenograms Exposure of the actual epiphyseal plate in young children would lead to damage of the growth center at the time of removal of the staples In older children, it makes no difference whether the plate is exposed or not

There is no discrepancy about the impaling of soft parts Any fascial or aponeurotic layers that move must be divided in the direction of their fibers and retracted The periosteum and cartilage do not move and may safely be impaled by the staples Dr White is right that the incision must be very accurate With practice and with biplane roentgenographic control, this is not difficult

CONSERVATIVE TREATMENT OF FUNCTIONAL DISORDERS OF THE FEET IN THE ADOLESCENT AND ADULT

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The following remarks will be limited to the conservative treatment of complaints of the human foot. Any earnest approach to these matters includes awareness that some feet remain free from common ailments. This emphasizes the presence of intrinsic and extrinsic influences which protect these feet from pain and disability in childhood and adult life. Within the scope of these influences has long been sought the formula for prevention and cure of the common ailments of the human foot.

These efforts are deep in time. Despite the multiplicity of thorough investigations, present-day complaints are the same as those which prevailed in 1819, when right and left shoes were an innovation. It is for these reasons that this subject is again under serious consideration. Awareness of the long background and respect for accumulated observations foster some doubt as to the possibility for the expression of original thought on this subject.

This presentation is based on the succession of events involved in the stance phase of the step. This is assumed to be a logical basis, because the common complaints related to the feet are provoked by and associated with the inherent and environmental conditions which are related to its functional requirements, as expressed in standing and walking. Therefore, a concept of pertinent principles governing foot function takes precedence over the details of therapeutic procedures.

Any fundamental approach to the solution of common complaints of and related to the foot requires consideration of the following points:

1. *Function*. This includes the functional significance of certain osteo-articular relationships, functional limitations of the extrinsic muscles of the foot, and the functional role of the osteo-articular relationships in the control of pronation.

2. *Pronation*. Clinical evidence indicates that strong extrinsic muscles do not assure protection against pronation, but that severe pronation in childhood can be significantly diminished by the effective application of the principles stated in Wolff's law.

3. *Pressure Relationships*. Through recorded pressures on the plantar surface of the foot, a correlation will be established between the location of most frequent complaints and the maximum work done by the foot in walking.

4. *Shoe-to-Foot Relationships*. A study of these relationships shows why the application of principles practised by Hugh Owen Thomas is effective in relieving certain complaints related to the fore part of the foot. Reference will be made to the prevailing disparity between the principles of foot function and the characteristics of the shoes in which they must do their work over a period of many years.

It becomes evident that we are to deal with variables of those clinical problems most frequently seen. The anatomical definitions of function have suggested a simple and direct explanation of the cause and treatment of such common complaints. However, time and an examination of large numbers of these structures deny such assumed regularity. The inherent variables unite to form a structural unit which serves the function of locomotion. The feet have, therefore, in common with other structures, a range of variations within the classification of normal.

When serious attention is directed to the function of the extrinsic muscles of the foot, as necessary for execution of the stance phase of the normal step, we recognize the

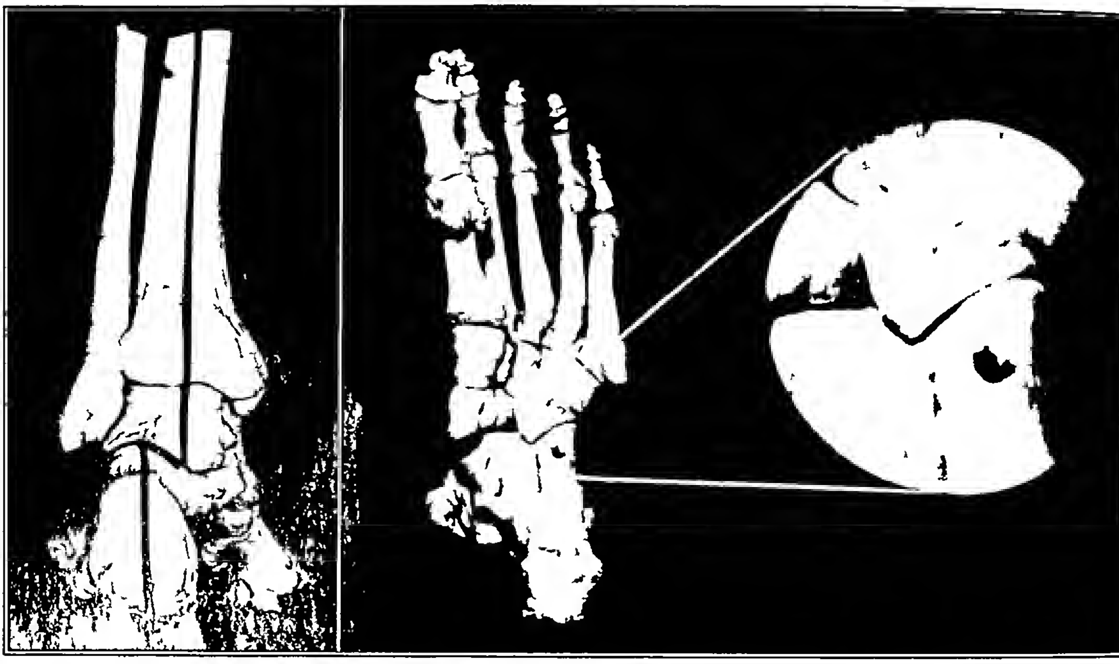

FIG. 1-A FIG. 1-B FIG. 1-C

Fig. 1-A: The axis of weight-bearing through the calcaneus is ±1.5 centimeters lateral to that of the tibia. (Reproduced, by permission, from *The Physiotherapy Review*, 16: 48, 1936.)

Figs. 1-B and 1-C: The calcaneocuboid lock effectively prevents pronation of the fore part of the foot when the calcaneus is held in alignment with the weight-bearing axis of the tibia.

limitations of definitions from the anatomical laboratories. It is from this single sourc that concepts of muscle function originated. These views, resulting from dissections o lifeless feet, were presented to explain the cause of and to define the resources availabl for relief of common ailments of the feet. Although such information was the initia requirement for the full development of gross anatomy, it was only a part of the premis required for the prevention and treatment of clinical problems. It seemed clear, there fore, that the remainder of the premise could not be defined without a method of quan titative analysis by which the functional characteristics of the foot in the stance phas of the step could be revealed.

Thus far, an effort has been made to separate certain theories based on gross anatom and their limitations when they are applied to those clinical problems of the feet which have been common to successive generations. One of the oldest of these problems is that of pronation. It is difficult to find in the literature evidence to support the claims made for the treatment of this condition, as recommended in current textbooks.

The functional characteristics of the osteo-articular structures involved in pronation should, therefore, be reviewed. In a previous communication [3], the authors called attention to the tibia as a weight-bearing column with the calcaneus serving as its foundation (Fig. 1-A). The axis of weight-bearing of the foundation is ±1.5 centimeters lateral to that of the tibia. The mechanism of pronation requires that the top of the axis of the calcaneus move medially toward the axis of the tibia.

Under those influences which maintain a parallel alignment between the axis of the calcaneus and that of the tibia, the full range of pronation of the fore part of the foot does not take place (Figs. 2-A and 2-B).

A patient (Figs. 3-A and 3-B) had suffered a compound, comminuted fracture of the right femur, in the distal third, complicated by complete severance of the sciatic nerve, four and one-half years before these illustrations were made. For nearly four years after healing of the fracture, he walked unaided by apparatus, without the development of any pronation of the right foot. The gait record (Fig. 4-A) shows that he expressed essentially normal characteristics in respective feet, as compared with the gait record of a normal individual (Fig. 4-B).

The absence of pronation in the right foot prevailed on the basis of osteo-articular relationships which maintained a parallel between the axis of the tibia and that of the calcaneus. In this position, the interlocking mechanism of the calcaneocuboid joint (Figs. 1-B and 1-C) effectively served its function; it stabilized the fore part of the foot on the heel. Also, the left foot of this patient is in good alignment; pronation is not a problem in such a foot. The skeletal characteristics of these feet, thus designed by nature, are functionally efficient; normal alignment is maintained between foot and leg, independent of functions of intrinsic and extrinsic muscles of the foot.

Another point of view is more commonly expressed, but rarely with convincing supportive evidence. It has long been stated that pronation is due to weak muscles. Exercises to increase the strength of muscles are, therefore, prescribed. Such a concept emphasizes only the strength of muscles; it fails to include consideration for the sequence and duration of contraction of muscles which must be reflexly coordinated for normal human locomotion.

There is still another omission. The premise that pronation is due to muscle weakness is not realistic as to the minimum expression of muscle contraction in standing. It is for this reason that in stance the feet have been regarded as "sinking into position".

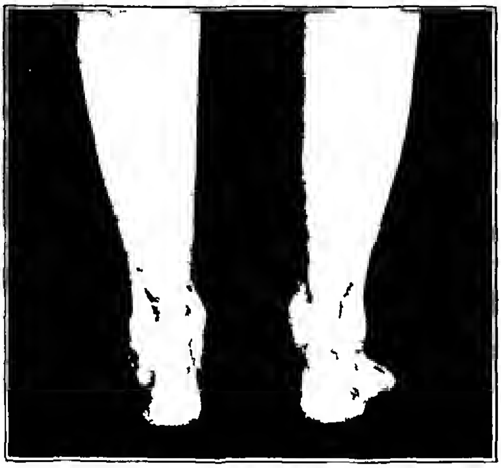

FIG. 2-A

FIG. 2-B

Fig. 2-A: Structurally normal male feet show pronation under the influence of weight-bearing.
Fig. 2-B: Parallel alignment between tibia and calcaneus is re-established through the use of heel cups with medial elevation.

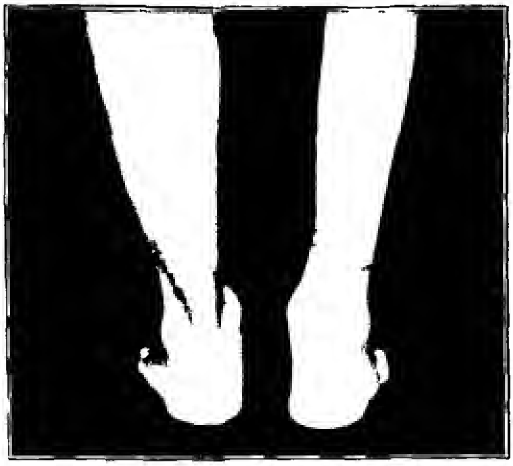

FIG. 3-A

FIG. 3-B

Four and one-half years after compound, comminuted fracture of the right femur and severance of the right sciatic nerve (not repaired), this patient stands and walks with freedom from pronation. The strong calcaneocuboid lock maintains parallel alignment of the right foot and leg in the complete absence of muscle function.

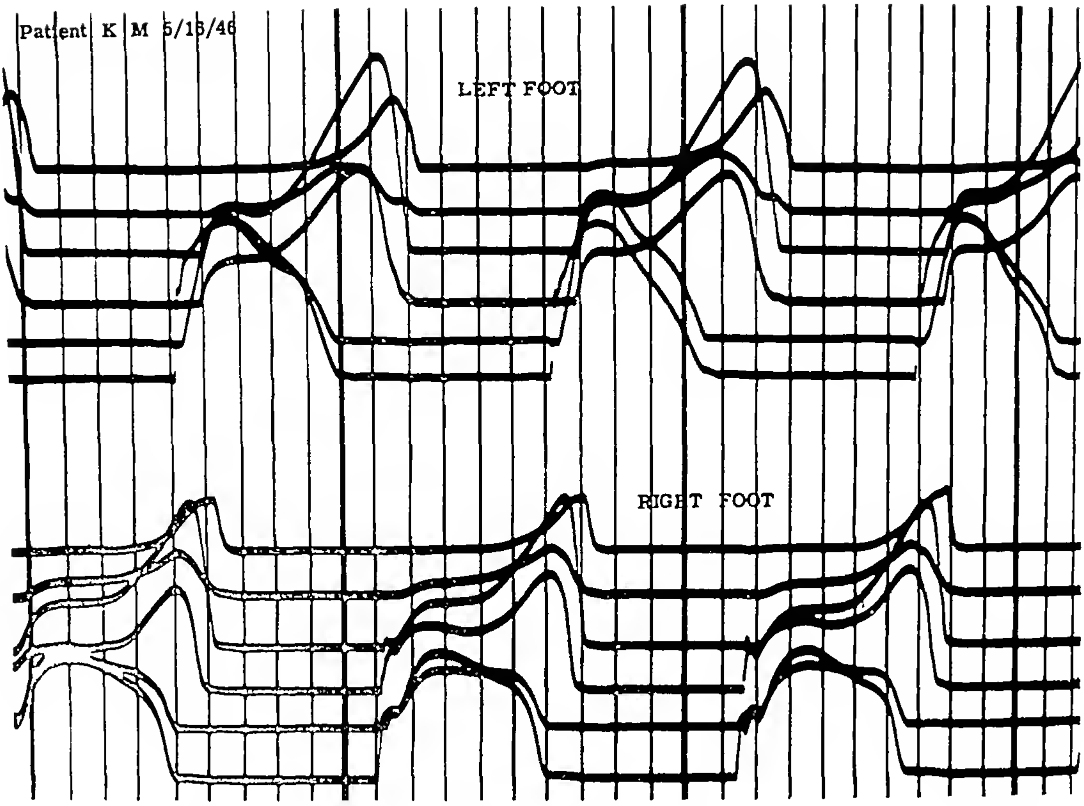

FIG. 4-A

Patient with severed right sciatic nerve shows little evidence of functional limitation, four years after accident (See Figs. 3-A and 3-B.)

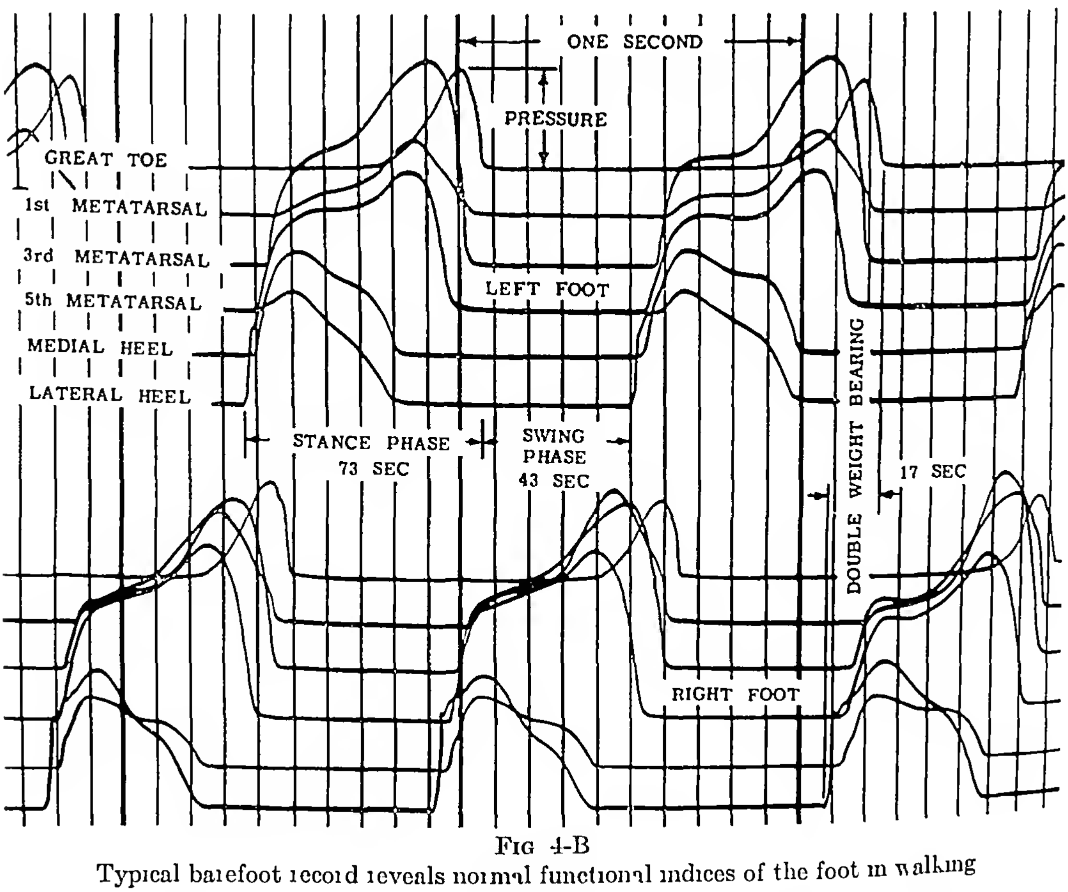

FIG. 4-B

Typical barefoot record reveals normal functional indices of the foot in walking

A nine-year-old girl illustrates why there is so little evidence in the literature that muscle weakness is the cause of pronation

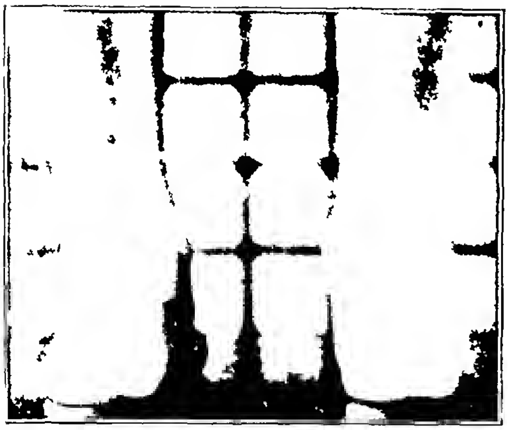

Fig 5-A

Fig 5-B

Fig 5-C

Fig 5-D

Four years of ballet training resulted in exceptional muscle strength and coordination Marked pronation in stance (Fig 5-A) is removed when the child stands on her toes (Fig 5-B), due to reflex contraction of posterior tibial muscles Well-developed muscles do not provide protection against pronation in the thoughtless, reflex act of walking (Figs 5-C and 5-D) During standing and walking, pronation is more marked in left foot than in right

After the child had had four years of ballet dancing, her mother became concerned about a painless left hallux valgus Bilateral pronation was noted (Fig 5-A) It was worse on the left when standing, when walking, there was no less pronation of either foot When she stood on her toes (Fig 5-B), the characteristic morphology of pronated feet was erased on each side In the latter position the posterior tibial muscle was reflexly contracted, in contrast with such functional requirement of the posterior tibial in the act of standing and walking

This patient is an exception in only one respect All nine-year-old girls have not practised ballet dancing for four years Despite the unusual strength and coordination of muscles which she had thus acquired, she did have significant bilateral pronation Observation of such combined relationships is frequent in daily clinical experience Therefore it seems clear that the time has come to discard an assumption which has been regarded as a fact Prevailing evidence does not support the view that pronation is due to weak muscles

Pronation will prevail in childhood whenever the functional characteristics of skeletal structures favor its presence, even though the extrinsic muscles of the foot are of normal strength A degree of pronation requiring treatment in childhood calls for application of Wolff's law, as illustrated by the following case

Photographs were taken of a boy, aged twelve years, after five years of treatment (Fig 6-A) Conventional metal plates had been used in an unsuccessful effort to relieve pain in and referred to the feet During this time, physical activities had been restricted by discomfort to a level far below normal His pronation was worse on the right and was

Fig. 6-A

Fig. 6-B

Fig. 6-A. Five years of treatment with metal plates had failed to relieve either pronation or associated symptoms in this twelve-year-old boy.

Fig. 6-B. Maintenance of parallel alignment of the axes of the tibia and calcaneus was accomplished through the use of shoes. At sixteen years of age, the patient was able to stand and walk barefooted without significant pronation, and was completely symptom-free.

accompanied by the appearance of abnormal physical and functional characteristics.

Treatment over a period of four years was limited to the use of shoes which maintained a parallel between the axis of the calcaneus and that of the tibia. At sixteen years of age, this patient stood and walked barefooted without pronation of the left foot and with only slight pronation of the right foot (Fig. 6-B). While attaining this end-result, he became symptom-free.

In the first case, the patient was protected from pronation by inherent functional characteristics of the osteo-articular structure, despite the total loss of sensory and motor function below the level of the right knee. In the second case, the patient had severe bilateral pronation, despite unusually well-developed strength and coordination of intrinsic and extrinsic muscles. In the third case, unusually severe pronation and accompanying physical and functional limitations had been unsuccessfully treated by the use of metal plates over a five-year period. Application of the principles described herein resulted in the permanent realignment of the osteo-articular relationships of the foot and leg, with accompanying freedom from symptoms.

The emphasis given to the relationship of the calcaneus to the tibia is not intended to imply that all clinical problems can be effectively alleviated merely by re-establishing parallel alignment between these two related units of the foot. The evidence indicates, however, that re-establishment of such parallel alignment does much to relieve symptoms which may be associated with pronation.

There should be little disagreement with the statement that the metatarsophalangeal area of the foot is the site of most frequent complaints by adults. Volumes have been

Fig. 7

Three frames from a 16-millimeter film, exposed at 270 frames per second, reveal the effectiveness of the anterior heel as a fulcrum for the fore part of the foot.

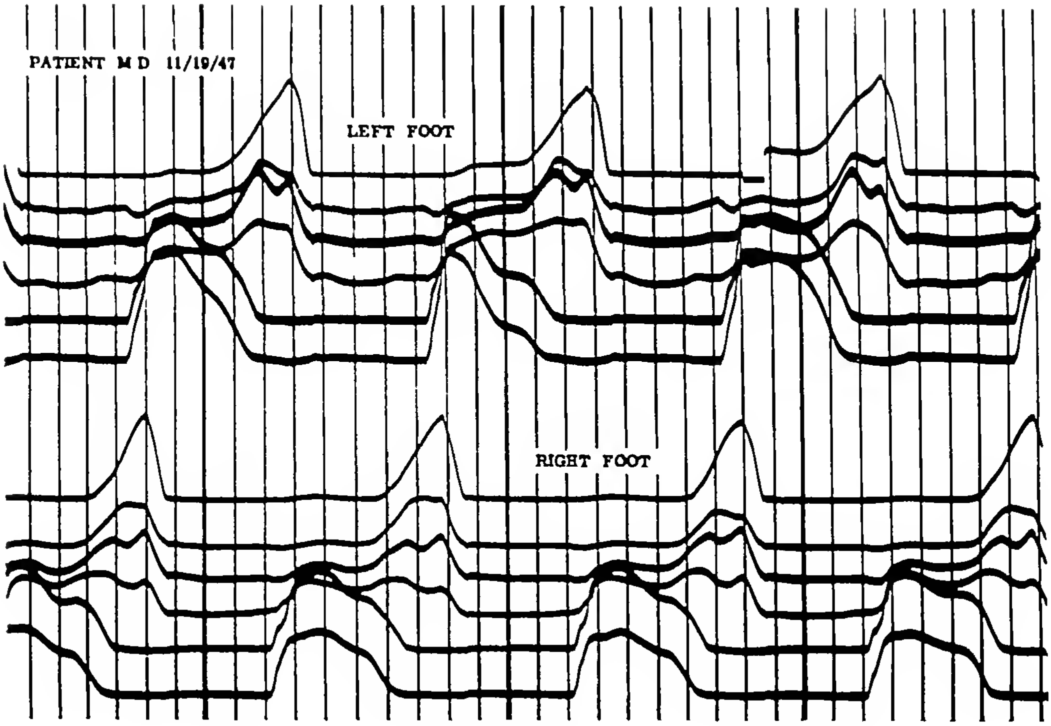

Fig 8-A

Oscillographic records show limited function of third and first metatarsal heads

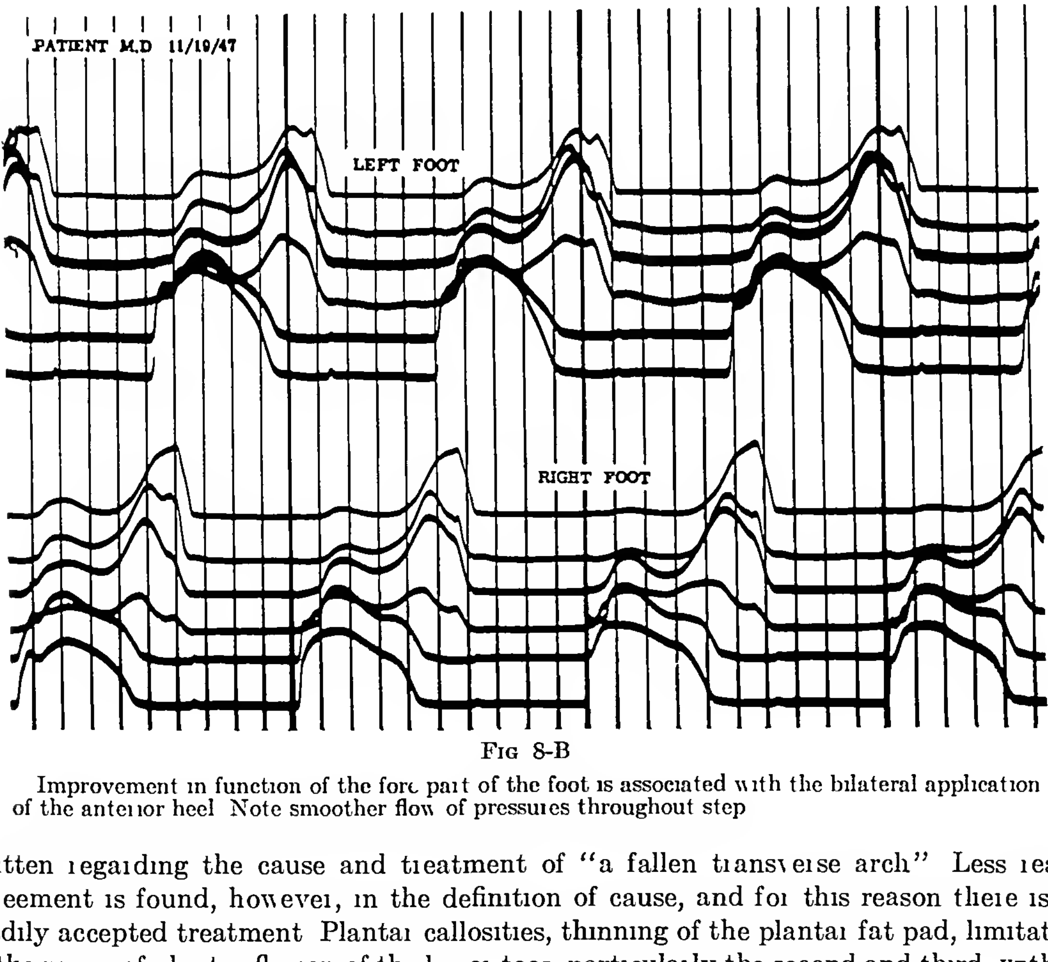

Fig 8-B

Improvement in function of the fore part of the foot is associated with the bilateral application of the anterior heel Note smoother flow of pressures throughout step

written regarding the cause and treatment of "a fallen transverse arch" Less ready agreement is found, however, in the definition of cause, and for this reason there is no readily accepted treatment Plantar callosities, thinning of the plantar fat pad, limitation in the range of plantar flexion of the lesser toes, particularly the second and third, with or

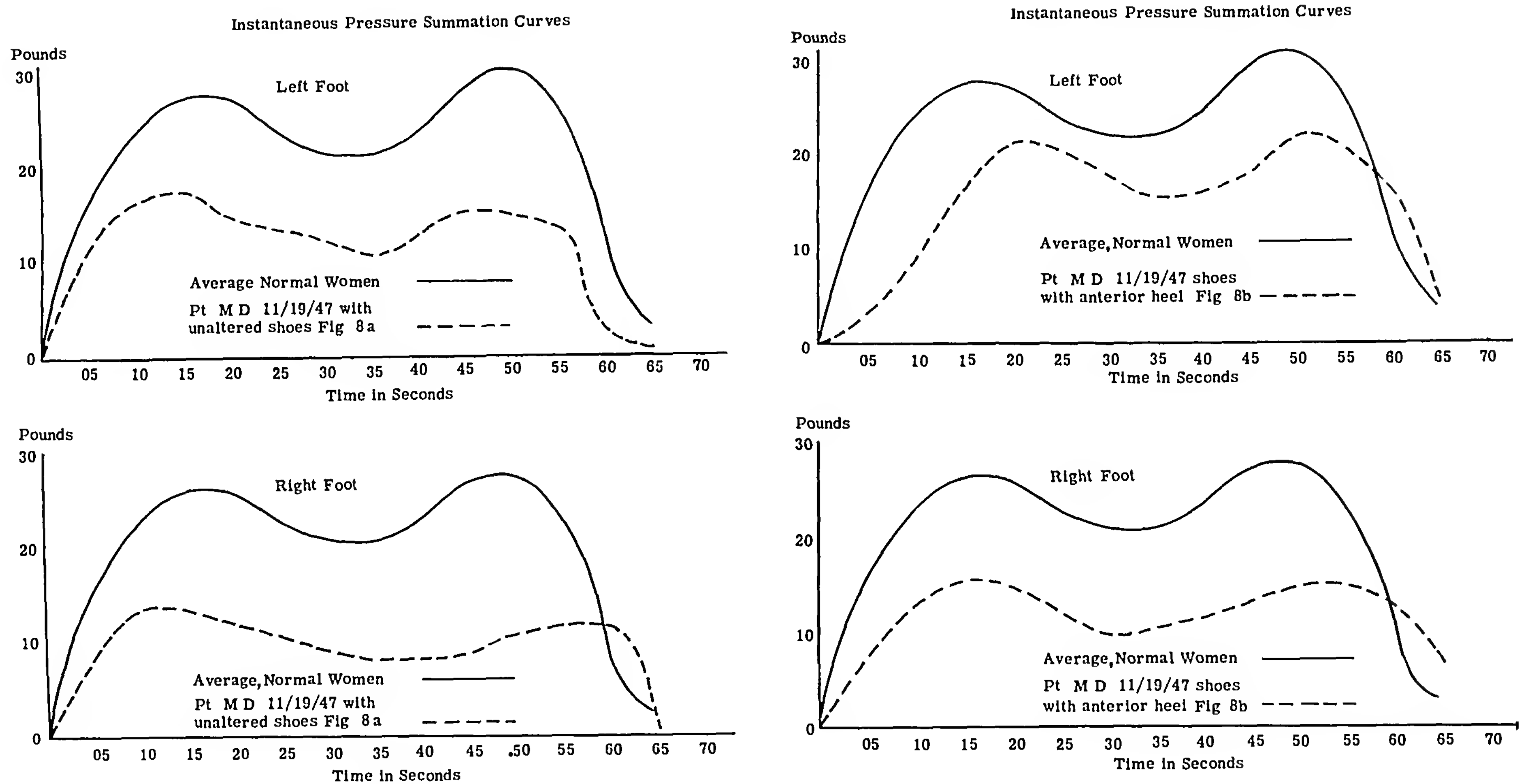

FIG 9

Summation curves of average normal women's gait, compared with summation curves made before and after application of anterior heel to patient's shoes

without bunions, hallux valgus, and corns, are commonly associated with complaints of discomfort at this level These are the expression of structural changes, due to mal-influences which have been long and repeatedly imposed upon the foot

These mal-influences are due in large measure to a common cause In certain instances, the beginning of trouble is directly related to a particular pair of shoes In feet which present a multiplicity of these structural changes and functional limitations, there is evidence of the harm imposed by shoes over a longer period of time

Early in the nineteenth century, shoes to fit right and left feet were considered an innovation, in marked contrast to the practice prevailing then of using shoes interchangeably Examination of the literature, however, indicates that this period marks the rediscovery of this practice, which " is a fashion of most remote antiquity"[2] Whether a shoe was made to fit either foot or an individual foot, however, available literature on the subject emphasizes the prevalence of corns, calluses, and foot deformities attributable to mal-fitting footwear Today, these common ailments of the feet, due to shoes, are still with us

At present, there is no generally accepted procedure by which children can assuredly escape the difficulties experienced by their parents It was more than three-quarters of a century before the making of shoes in pairs became an established practice Since then, achievements in mass production have been remarkable and the quality of shoes has attained high standards, but the clinical problems associated with feet working in shoes are still present

Among those concerned with the problems of shoemaking, there is general agreement on one point Regardless of the quality of material and workmanship, a shoe is no better than the last over which it is made Such a point of view is of long standing In 1889, T S Ellis stated that the clothing of the foot ought to conform to its functions To attain this objective, his considerations of the shoe began with the recommendation that "the form of boot-lasts correspond in shape to that of feet in action"[1] However, there has been essentially no change in the art of last-making, the shape is determined by many factors other than the preservation of foot function

It is for these reasons that we can account for the heterogeneous variety of devices used in an effort to solve the problems of plantar callosities, corns, et cetera They are essentially the same as those which have been applied, with varying degrees of effectiveness, for decades Among these, personal experience has demonstrated the effectiveness of the anterior heel, as used by Hugh Owen Thomas When properly applied, it is frequently effective in relieving pain from plantar callosities at the metatarsophalangeal level, and assists passive and active exercises to re-establish plantar flexion at the metatarsophalangeal joints, which is so essential to the functional well-being of the fore part of the foot

The anterior heel (Fig 7) provides a fulcrum over which the metatarsal phalanges are plantar-flexed Two clinical advantages result First is the rapid relief of symptoms, which is more consistent than from any other single mechanism used for relief of discomfort originating in the metatarsal area Second is the prolonged effect which frequently results from its temporary use Patients often find that the use of such altered shoes for a varying period, accompanied by passive and active exercises, results in sufficient restoration of comfort, so that they can occasionally use unaltered shoes without discomfort

The record of quantitative analysis, showing the gait of a patient prior to the application of the anterior heel, is presented (Fig 8-A) It is evident that the third and first metatarsal heads are not performing their normal function smoothly and rhythmically Because of the pain in large callosities centering over the third metatarsal heads, the pressures are low and uneven Propulsion from the great toe is characterized by a sudden sharp rise and decline Following application of the anterior heel (Fig 8-B), both records and summation analysis curve (Fig 9) show a more nearly normal functional pattern These

changes in function were accompanied by complete freedom from symptoms, and eight months later the callosities were absent

The inherent weaknesses of the human foot have long been recognized Its potential strength and methods for best utilizing prevailing structural advantages have not received equal consideration As long as information is drawn only from visual observation of the living foot and from anatomical studies of the static structure, we shall fail to reach a maximum understanding of the requirements of the human foot for its most efficient functioning Until recorded evidence capable of quantitative measurement and interpretation is more widely applied, therapy, both conservative and operative must continue to be instituted and evaluated empirically This is particularly true in the structurally normal foot which is dependent upon conservative treatment for the alleviation of pain and fatigue and for the restoration of functional efficiency

Traditional methods of treatment lean heavily upon "corrective" shoes and the addition of pads, insoles, lifts, et cetera to conventionally designed footwear The characteristics of conventional footwear and the corrective devices employed in treatment are based upon a study of the foot at rest Within the scope of these resources, the foot is subjected to an infinite variety of influences, which are the result of opposing theories of shoe design and of therapeutic measures

Until the function of the foot and the requirements best suited to preserving its function have been thoroughly evaluated on a quantitative basis, such controversial methods must prevail, with the recurrence in successive generations of the same complaints related to the feet We have presented here some results of the clinical application of instrumentation designed specifically to provide a quantitative definition of the functional requirements of the human foot in action It is our hope that the application of quantitative measurement to the study of these problems may ultimately lead to the more certain prevention and the effective treatment of common complaints of the human foot at work

SUMMARY

Pronation in childhood is an expression of deficiency in the function of the intrinsic osteo-articular structures of the foot By application of the principles of Wolff's law pronation may be greatly improved or entirely eliminated by the time the child is sixteen In both children and adults, the preservation of function of the intrinsic and extrinsic structures essential to normal stance and locomotion is required for maximum efficiency and greatest freedom from discomfort The shoes in which feet must work constitute the major cause of these problems common to successive generations Excellence in quality of footwear cannot assure that the feet will be free from functional impairment The structural and functional relationship between foot and shoe is determined by the last over which the shoe is made The design of lasts has been determined by a combination of empirical influences, without benefit of measurements necessary for the preservation of function of the intrinsic and extrinsic structures essential to efficiency and comfort in stance and locomotion

Full understanding of the needs of the human foot in action awaits the further application of measurement to the study of foot dynamics Proved principles can then replace opinion in the design of shoe lasts and in the application of therapeutic measures

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TIBIAL TORSION *

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The phrase "tibial torsion" has become the commonly accepted term to describe any twist or rotation of the tibia on its longitudinal axis The term has been used in connection with the rotation which frequently accompanies club-foot, and to explain the crippling results of reductions which fail to secure proper torsional alignment in fractures of both bones of the leg No emphasis has been placed upon the developmental changes which produce an external rotation of 20 degrees in the normal tibia, or upon the functional and cosmetic handicaps which result when this rotation fails to take place In adult life, the pigeon-toed gait often produces a psychological disability There are no reports available to show either the percentage of variations in torsional alignment in the population, or the torsional changes which may be expected during the growth period Without an understanding of these factors, the problem of correction is difficult to approach satisfactorily

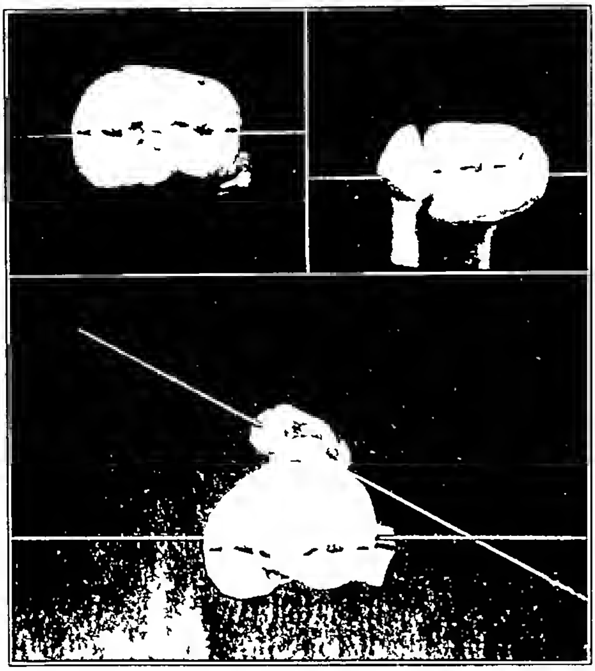
METHODS OF MEASUREMENT

Tibial torsion may be defined as any twisting of the tibia on its longitudinal axis which produces a change in alignment of the planes of motion of the proximal and distal articulations The knee and ankle function essentially as hinge joints The authors have elected, as the base position for measuring torsional variations, that position in which the planes of motion are parallel Two types of rotational aberration are then possible,—internal and external Internal torsion is present when the rotation is in the direction of the medial malleolus, and external torsion, when it is in the direction of the lateral malleolus For recording purposes, the authors have designated the base measurement as zero (0) degrees, internal torsion as minus (−) the number of degrees and external rotation as plus (+) the number of degrees

The accurate measurement of torsion presents certain difficulties in the living subject, but may be readily ascertained on the skeletal specimen by means of the tropometer The longitudinal axis of the tibia is located halfway between the centers of the condylar articulating surfaces proximally, and the malleoli distally If a steel pin is passed through the proximal articulation parallel to a line drawn through the centers of the articulating surfaces, and another pin is passed through the distal articulating area parallel to a line between the centers of the malleoli, one may visualize the axis of motion of the joints When the specimen is held so that the proximal articulation faces the observer, the torsion present may be observed by looking along the longitudinal axis of the bone (Fig 1) The tropometer is used to measure this rotation in degrees The bone is held in the tropometer by a pin, inserted into the distal end of the bone The pin through the proximal articulation is fixed to the vertical standard A protractor, placed directly beneath the distal pin, permits one to ascertain the number of degrees of rotation (Fig 2) Our most accurate measurements were obtained in this manner

Approximate measurements can be obtained in the adult patient by the use of a roentgenogram The film holder is placed beneath the plantar surfaces of the feet, while the patient sits with his knees flexed to 90 degrees and with the medial borders of his feet parallel to the medial borders of his thighs When the exposure is made with the tube above the knees, the roentgen rays are nearly parallel to the longitudinal axis of the tibia and cast an image of the malleoli and feet upon the film A line drawn along the medial border of the roentgenographic shadows of the bony structures of the foot will be approxi-

* This study was made possible by the M J Connell Research Fund



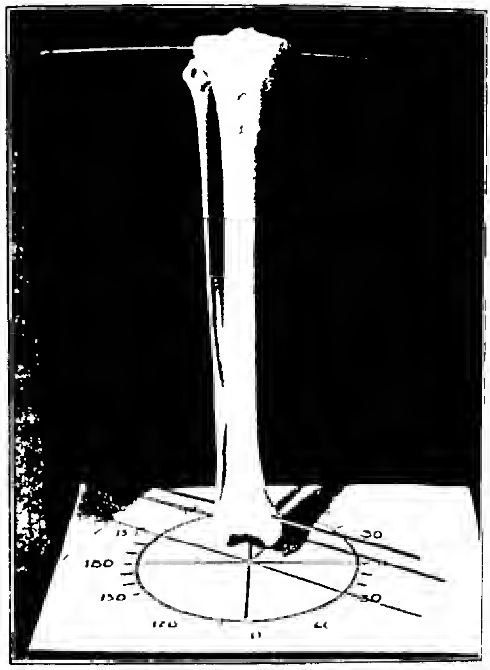


FIG. 1 FIG. 2

Fig. 1. Pins inserted through the articular axes of a normal tibia to show external torsion.
Fig. 2. Model demonstrates the method of obtaining tropometric measurements.

FIG. 3

Method employed to evaluate torsion clinically.

mately at a right angle to the articular axis of the knee. The angle formed by the intersection of this line with another line drawn between the malleolar shadows, when subtracted from 90 degrees, will give the measurement of tibial torsion in degrees (Figs. 4-C and 4-D).

This method could not be applied to young children, for their cartilaginous epiphyses cast no satisfactory roentgenographic image. Therefore, a paste, composed of bismuth subcarbonate and collodion, was applied to the skin over the point of maximum palpable projection of the malleoli, in order to demonstrate their location. This technique, while not entirely satisfactory, clearly demonstrated the extremes of rotation in some of the children examined.

In the majority of instances, torsion was estimated on the basis of physical examination alone. The child sat in front of the examiner, with the knees flexed to a right angle. The examiner placed his left hand beneath the popliteal area, supporting the patient's foot from pressure against the floor, while he placed the thumb of his right hand on one malleolus and the index finger on the other. Then, by looking down the longitudinal axis of the tibia, he could estimate the number of degrees of tibial torsion (Fig. 3). This was found to be the most practical method of measurement.

The Adult Tibia

Before any consideration could be given to torsional alterations during the growth period, it was necessary to establish the normal or average structural picture of the adult tibia. Since the knee and ankle act as hinge joints, one would expect them to function most efficiently when their planes of motion were parallel. The authors' measurements do not show this to be the case.

Data were obtained from tropometric measurements of tibiae from forty adult skeletons.* Twenty right tibiae were measured, and the results were as follows: +32, +24, +16, +40, +11, +28, +36, +14, +34, +30, −4, +21, +14, +28, +18, +22, +34, +18, +14, and +12 degrees. The average was +22.1 degrees.

Twenty left tibiae were measured, with the following results: +29, +13, +27, +18, +35, +22, +8, +15, +17, +14, −9, +26, +16, +12, +31, +23, +31, +17, +25, and +27 degrees. The average was +19.8 degrees.

The average of the right and left tibiae combined was +20.9 degrees.

These measurements corroborate the findings of Le Damany, who measured 100 tibiae and found that fifty right tibiae averaged +25 degrees of torsion, while the fifty left averaged +22 degrees, with a combined average of +23 degrees. He also measured five right and eight left tibiae of specimens from a prehistoric age when shoes were unknown, and found that the average torsion was +25 degrees. The five right tibiae measured +30 degrees, while the eight left measured +22 degrees. Shoes have apparently played no part in the development of external tibial torsion. From these data it may be concluded that the normal tibia will exhibit about 20 degrees of external torsion.

Two hundred adults were examined in order to determine the incidence of internal torsion in the adult population. Of 100 women examined, 5 per cent. showed internal torsion, 2 per cent. showed it to a degree severe enough to cause difficulties in walking. Of 100 males examined, 3 per cent. exhibited internal torsion, while 1 per cent. had a pigeon-toed gait sufficient to cause psychological sensitivity.

Because internal torsion is common among the Japanese, the authors examined fifty adults of Japanese extraction, who had been in the United States. Three of these, or 6 per cent., had internal torsion. This percentage was not greatly different from that obtained in the 100 adult Americans examined; however, of eight Japanese who had spent their childhood in Japan, all showed internal tibial torsion. Such a deformity could be expected in Japan, if rotational stresses play any part in abnormal tibial development, for the Japanese have few chairs and sit upon the floor, with their legs folded under them and their feet turned inward, directly beneath the buttocks. Such a posture for several hours a day, with the superincumbent weight of the body producing an internal torsion on the tibia, can scarcely be ignored as a factor in producing a torsional deformity.

TORSIONAL CHANGES DURING THE GROWTH PERIOD

The mean or average tibial torsion is 20 degrees. The authors believe that a variation of 20 degrees—that is, any measurement from 0 to +40 degrees—is consistent with normal appearance and function. Therefore, only those cases with internal torsion (torsion measuring a minus number of degrees by this method) were considered to be abnormal. Likewise, only subjects with severe external torsion (torsion of more than 40 degrees) were considered to be abnormal.

Intra-Uterine Period

During the intra-uterine period of growth, there is an inward rotation of the legs of 90 degrees, as they approach their final position. The limb buds develop at right angles to the trunk and then extend in a lateral direction. The knee joints are developed while in a flexed position, and the plantar surfaces of the feet face the trunk. As they descend on the trunk, the legs rotate 90 degrees internally, so that the knees face anteriorly and the plantar surfaces of the feet point in a posterior direction. The legs usually remain in a flexed position until after birth. Tropometric measurement of these cartilaginous bones is difficult. One nine-month stillborn child was measured, and was found to have 0 and −5 degrees of rotation of the right and left tibiae, respectively. Le Damany measured

* No attempt was made to determine the sex of the individual skeletons.

five infants at birth and found the average to be +4 degrees for the group. These figures indicate that the infant has very little tibial torsion at birth.

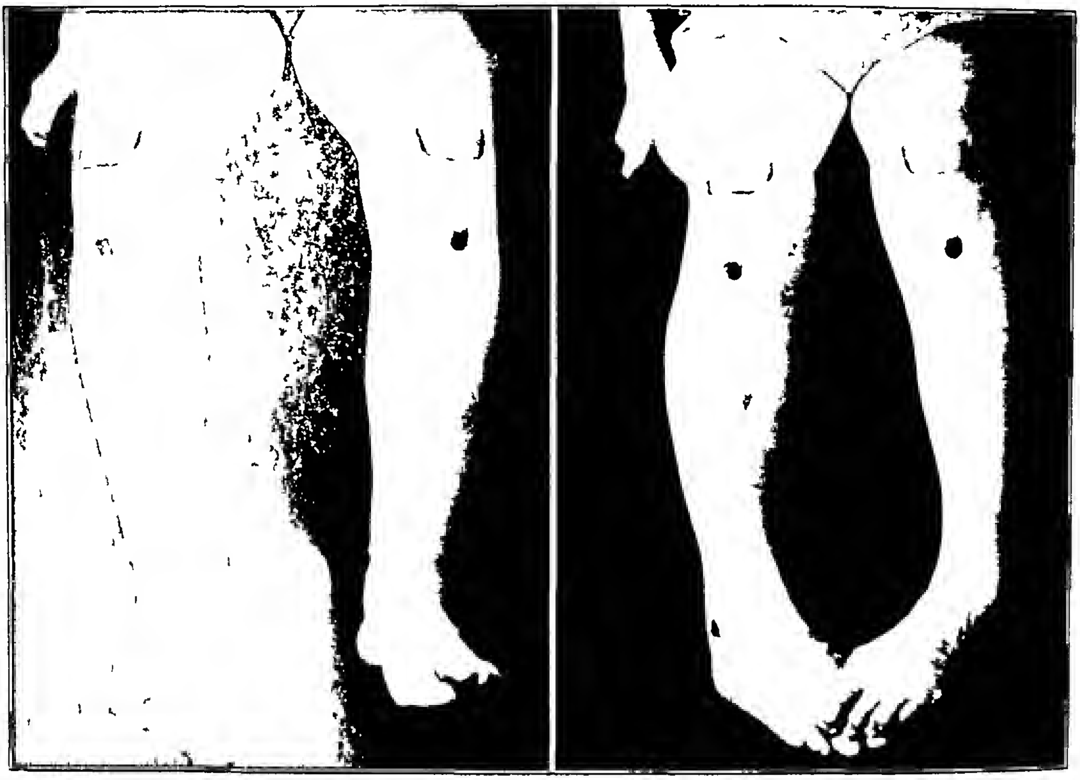


FIG. 4-A

Internal torsion in an adult. When the feet are in a normal position, the patellae and tibial tubercles point outward; when the patellae and tibial tubercles are in a normal position, the lateral malleolus becomes prominent.

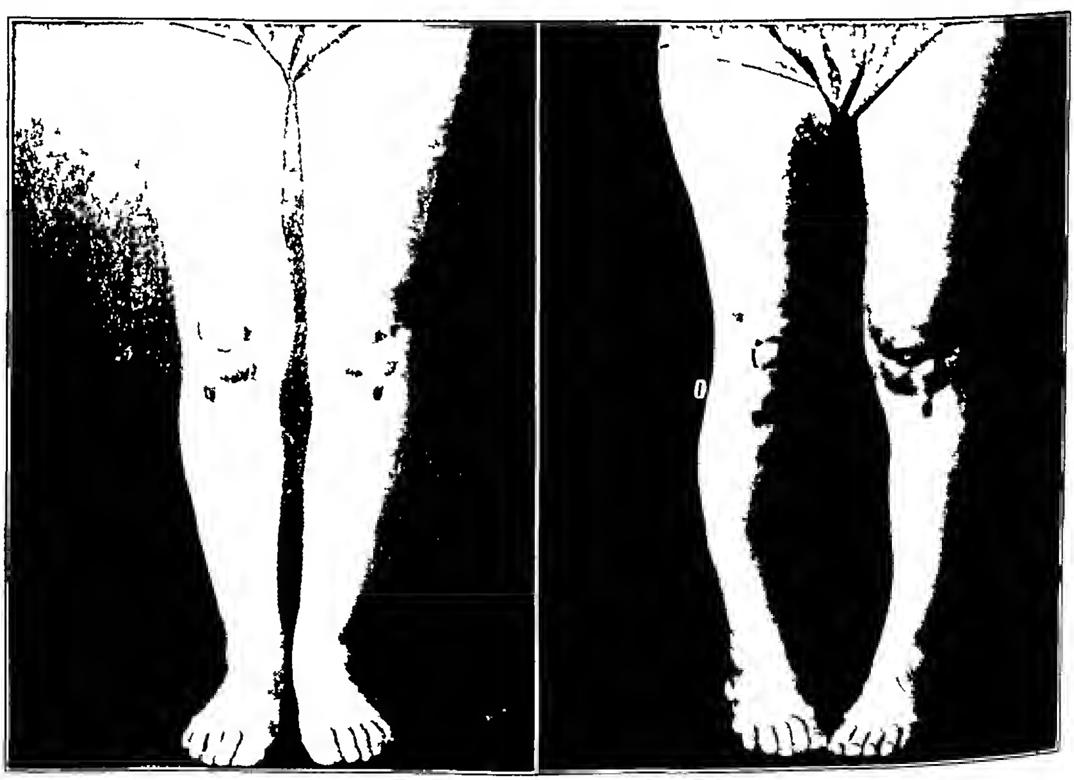


FIG. 4-B

Compensation for internal-torsion deformity by external rotation of the knees (left). Non-compensated position which children usually assume (right).

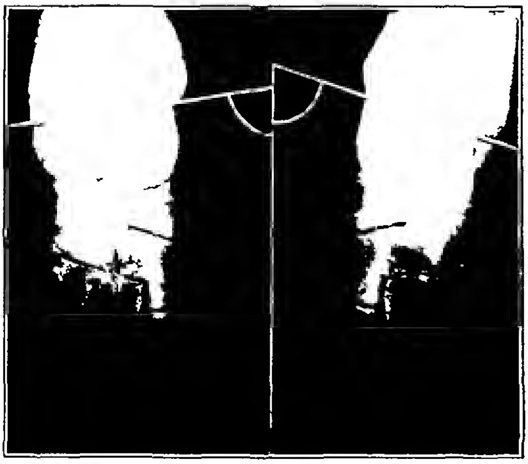


FIG. 4-C

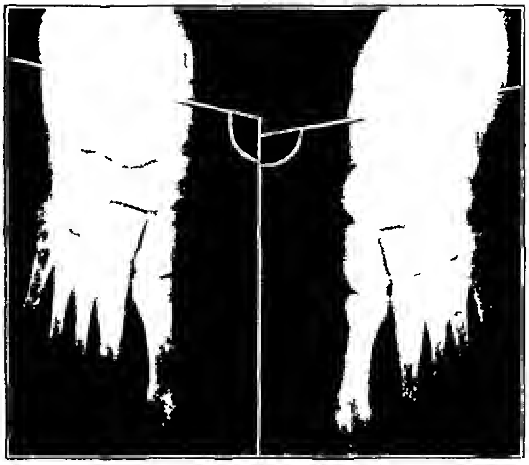


FIG. 4-D

Fig. 4-C: Roentgenograms show internal torsion of −10 degrees on the right and −18 degrees on the left.

Fig. 4-D: Roentgenograms demonstrate external rotation of +13 degrees on the right and +12 degrees on the left.

The First Year

Tropometric examination of infants was almost impossible. One deceased infant, aged twelve months, showed +18 degrees on the right tibia and +12 degrees on the left. Estimation of the torsion by other methods was found to be too inaccurate for the purposes of this study.

The Second Year

Fifty normal infants, all in their second year, were examined clinically. Thirty per cent. walked with the toes turned inward, and on clinical examination showed no evidence of external torsion. One child displayed 15 degrees of internal torsion, bilaterally. Thirty-four children walked with their feet pointed straight ahead or turned slightly outward. One child showed considerable relaxation of the ligamentous structures of the feet, and about 35 degrees of external rotation. None of the fifty children showed any evidence of metatarsus varus or other abnormalities of the feet or legs.

The Period from Five to Seven and One-Half Years

In order to corroborate or refute the widespread opinion that all torsional deformities are corrected spontaneously, approximately 1,500 school children in Los Angeles were examined. The schools in which this survey was carried out were in areas representing an economic cross section of the city, and did not include any children who for some structural deformity had been referred to special corrective classes. Ten per cent. of the 192 boys, who were from five to seven and one-half years of age, showed internal tibial torsion. One half of these, or 5 per cent., had severe deformities. Of 186 girls in the same age group, 8.5 per cent. showed internal tibial torsion.

The Period from the Twelfth to the Fourteenth Year

Four hundred boys were examined, 8 per cent. of whom showed internal tibial torsion; of the 400 girls examined, 9 per cent. had internal torsion.

It is recalled that about 4 per cent. of the adults examined showed some internal torsion, and that in the group aged five to seven and one-half years, a 9 per cent. incidence was found. If we assume that the greatest error in measurement is made in young children, and that adaptive changes have made the condition less striking in the adult, it would appear that relatively little correction of the internally rotated tibia takes place after the

age of seven In other words, whatever torsion is present in a seven-year-old child will probably still be present when he becomes an adult

CLINICAL APPLICATION

In this survey, approximately 1 per cent of the adult population demonstrated a serious degree of internal torsion, indicating that about one million people in the United

FIG 5-A

FIG 5-B

Sleeping positions which may play a part in the development of internal torsion in children

FIG 6-A

FIG 6-B

Tibial torsion in a child, two and one-half years old

States may be affected. Because of both the psychological and the functional handicaps which this condition has produced in some of the adults examined, it is apparent that orthopaedic surgeons should be more concerned with these deformities and should institute corrective measures early in the formative years. These deformities are more striking among women, for they are accentuated by high heels and exposed legs. The case history of one such woman is reported.

A white woman, twenty-seven years old, had been aware of deformity of her legs since adolescence; she considered her pigeon-toed gait to be the result of bowed legs. The deformity was a handicap both psychologically and physically. She had suffered no serious childhood diseases or deficiencies, and her family had been assured by their physician that she would outgrow her toed-in gait. Examination of the lower extremities revealed no bowing, but severe internal torsion. She could stand with her feet parallel only by turning her knees outward (Figs. 4-A and 4-B). Roentgenograms of the legs revealed normal bone structure. The internal torsion, measured on the roentgenogram, was −18 degrees on the left tibia and −10 degrees on the right (Figs. 4-C and 4-D).

Approximately eighty children were treated by the authors for internal torsion. In each case the parents were concerned with the toed-in position of the feet while the child was walking. In many cases, the mother volunteered the information that the child was in the habit of sleeping upon the abdomen with the feet turned inward, and with the lower extremities flexed at the hip and knee. Some thought that this might have contributed to the deformity (Figs. 5-A and 5-B). Occasionally, the torsion was accompanied by metatarsus varus or bowing of the lower third of the tibia, but in most cases it was the only deformity present (Figs. 6-A and 6-B).

Two children had external torsion. One, seven years of age, had severe knock-knee and external torsion. He was in the habit of sitting on his legs, with the knees flexed and with the feet externally rotated, so that the medial border of the foot rested upon the floor. Standing, with the feet turned outward to 90 degrees, he was able to flex the knees straight forward. The other patient was a boy of sixteen who, at thirteen years of age, had suffered a fractured spine and paraplegia. Prior to the injury, he had had no deformity

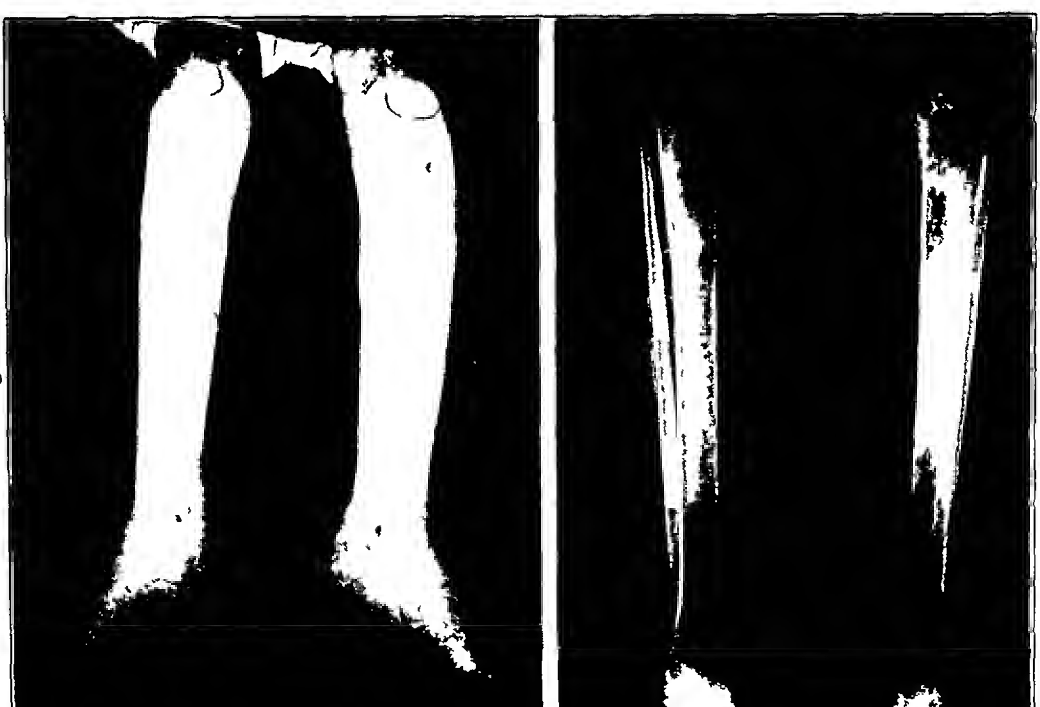


Fig. 7-A Fig. 7-B

Severe external torsion produced by gravity and pressure of bedclothes on legs of a growing paraplegic child.

of the legs, but after three years of recumbency, with gravity and bedclothes forcing his legs into external rotation, a severe deformity had developed (Figs. 7-A and 7-B). Perhaps the same deforming forces which produced such extreme external torsion in this paraplegic play a part in the production of external torsion in the normal individual.

TREATMENT

In the past, some surgeons have treated tibial torsion by osteotomies[1,2,3,5,7,8]. Others have employed derotation exercises which the parents perform at home, or have applied a wedge on the outer borders of the soles of the shoes, but for the most part, treatment of this rather common entity has been ignored. Six years ago, one of us (W. S.) instituted a simple and effective treatment which consists of having a child wear a modified Denis Browne splint during the sleeping hours. Shoes are attached to the foot plates, and the plates are fastened in a toed-out direction of 20 degrees at first, and are slowly adjusted until they point outward as much as 45 degrees in severe cases. The length of the bar used to separate the feet has been reduced to six inches to prevent the possibility of the development of knock-knee.

The most frequent comment by the parent at the end of four to six weeks is that the child appears to walk much more normally. This noticeable improvement, however, antecedes actual anatomical correction by four to six months. The authors discontinue use of the splint before all of the correction has occurred, allowing for final compensatory changes in the subsequent growth period.

CONCLUSIONS

1. The normal adult tibia exhibits about 20 degrees of external torsion.
2. Extremes of tibial torsion, internal or external, if permitted to persist, produce handicapped members of our adult society.
3. Infants and pre-school-age children have less external rotation than adults.
4. Normal developmental changes do not correct extremes of torsion to any great extent, especially in school-age children.
5. Positions and other attitudes of posture will produce rotational changes in the tibiae, depending upon the direction of the rotary stress applied.
6. Correction of these deformities is possible in the growth period by the application of a simple night splint which produces a rotational stress in a direction opposite to that of the deformity.
7. Deformities which are present at three years of age or older should be corrected at that age; younger children with torsional deformity should be observed in order to determine what compensatory changes may occur.

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THE MECHANISM OF THE STRUCTURAL CHANGES IN SCOLIOSIS *

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Structural scoliosis may be defined as that form of lateral curvature of the spine which is accompanied by the development of wedging and deformation of the vertebrae It should be differentiated from functional scoliosis, which is not accompanied by vertebral wedging or deformation This paper will attempt to describe the mechanism of development of the *structural* changes in scoliosis

Certain facts in the clinical behavior of scoliosis are noteworthy Wedging and deformation of the vertebrae are noted only in curvatures which begin before growth is complete These changes do not develop in an adult, they stop progressing when growth stops These facts suggest that a deformity which can occur and progress only during the period of growth must be related to *epiphyseal growth* This was also suggested by Volkmann and by Bisgard and Musselman, who believed that wedging is due only to asymmetrical vertebral growth In the report of the Research Committee of The American Orthopaedic Association, a number of clinicians supported the view that "curvature is the result of a growth disturbance at the epiphyseal plate of the vertebrae, possibly related to an osteochondritic process or to epiphyseal trauma with an associated deficiency, either metabolic or dietary"

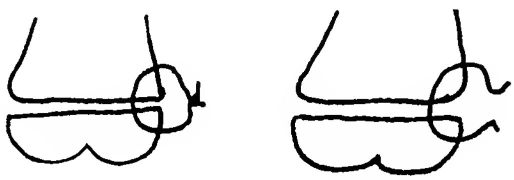

FIG 1-A No growth

FIG 1-B Growth

Haas's experiment

Moreover, typical "idiopathic" structural scoliosis does not occur in quadrupeds, and it has been noted that bed rest may halt the progress of such scoliosis in children In over thirty cases in which the condition was advancing, Cobb kept the children in bed for twenty-two hours per day Except in one case, no progress was noted after three months This suggests the familiar concept that the pressure of weight-bearing in the upright position may be important

The relationship between pressure and epiphyseal growth has been mentioned by various authors, including Appleton, Hueter, and Volkmann Haas showed that compression of an epiphyseal plate by a wire will arrest growth (Fig 1-A), the wire itself without compression has no effect (Fig 1-B) Growth is resumed after the pressure has been removed

With these factors in mind, the mechanics of a scoliotic curve can be considered Figure 2 reveals that, in curvatures of the spine, there must be compression of the vertebral bodies on the concave side of the curve and distraction on the convex side, caused by the action of gravitational forces in the erect position This is also indicated by the narrowing of the intervertebral disc on the concave side and its expansion on the convex side in the roentgenogram of a scoliotic spine (Fig 3)

The tremendous magnitude which this pressure may assume can be realized from a diagram of the forces acting upon the vertebral body (Fig 5) Let x represent the distance perpendicularly from the line of center of gravity to the nearest edge of the disc Let y represent the distance from the pivot point or fulcrum (corner of the body) to the ligament

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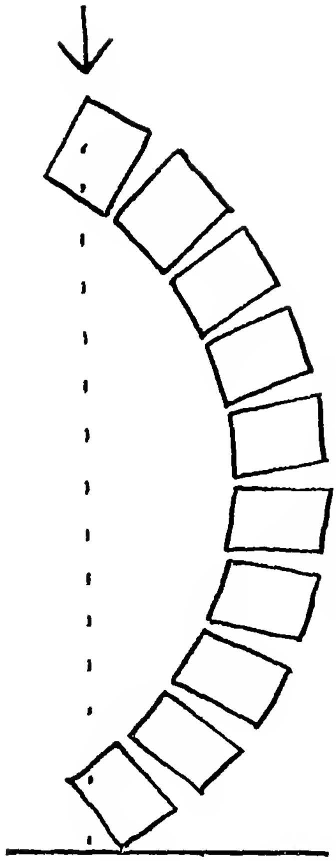

FIG. 2

Fig. 2. Action of superincumbent weight on a curved column of blocks.

Fig. 3. Typical "idiopathic" structural scoliosis.

Fig. 4. Post-thoracoplasty scoliosis.

FIG. 3

FIG. 4

or supporting structure on the convex side of the curve. A simplified diagram of such a rela-tionship is shown in Figure 6. Let us assume that the seated figure weighs fifty pound-. Then the product of force times distance equals the product of force times distance (50 × equals 250 × 1), and the weight on the fulcrum will equal 300 pounds. Hence the weigh concentrated on this small section of the epiphysis will equal (if w represents superin-cumbent weight) w plus $\frac{wx}{y}$.

In cases where the lateral displacement of the apex of the curve from the centr line of gravity is equivalent to five or six vertebral diameters (and this is not infrequent) the weight concentrated upon this small corner of the epiphysis may be six or seven time the total superincumbent weight. Here, then, is tremendous compression concentrate upon a very small section of the growing epiphyseal plate,—apparently enough to arre the growth in height on the concave side and to lead to the typical wedged vertebra charac teristic of the apex of a scoliotic curve. Wedging can be explained by unilateral epiphyse growth arrest, a comparison of Figures 3 and 4 will show that the same tremendous com pression, applied after growth is completed, does not cause wedging. The absence c epiphyseal rings on the concave side (Fig. 18) indicates a similar effect, since the rings ar subject to the same pressure as are the epiphyseal plates.

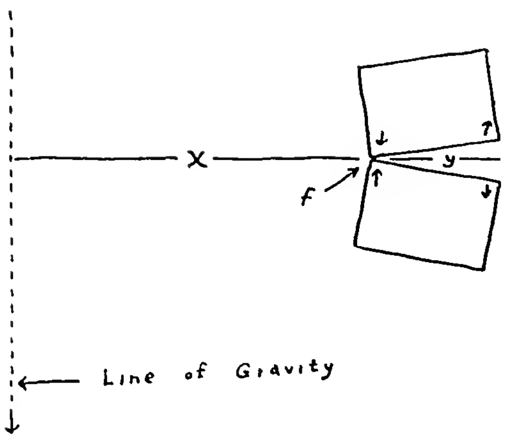

Fig 5

Forces acting on an apical vertebra in scoliosis

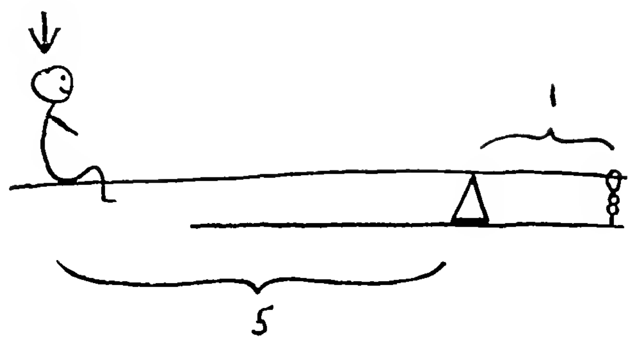

Fig 6

Representation of forces in Fig 5

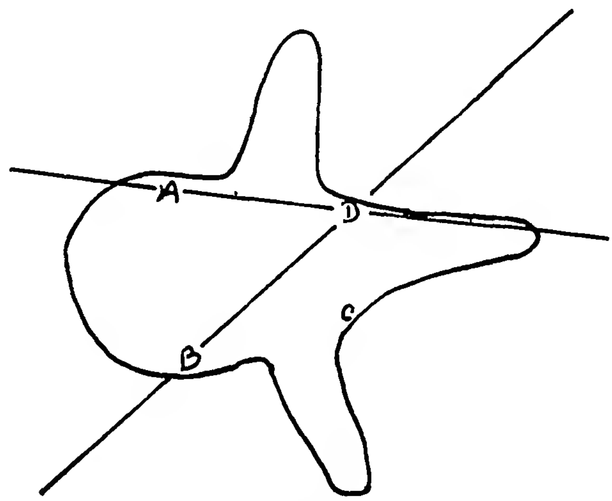

Fig 7

Diagrammatic representation of vertebrae, as seen from above

(This is an approximation, and not a quantitative expression of the forces acting upon the epiphysis It does not take into account the soft-tissue tension or the resistance to stretching on the convex side of the curve, which has the effect of increasing the distance y and diminishing the weight on the fulcrum For example, examination of a specimen of a scoliotic spine at the New York University College of Medicine revealed marked hypertrophy of the *intertransverse* ligament on the convex side Certainly y is equal to more than one vertebral diameter in this case Neither does it take into account the supportive effect of impingement of ribs and pelvis on the concave side, and the resistance of the rib cage to deformation Moreover, the sharp corner of the vertebral body is soon flattened off by the inhibition of growth, and a progressively larger area of the body acts as a fulcrum and supports the superincumbent weight, thus diminishing the load per unit of area)

Examination of a typical vertebra as seen from above (Fig 7) shows that the normal spine may be considered to be supported at four points, denoted by A, B, C, and D Lateral bending in the normal spine may be considered to take place through the axis A–D If support A is depressed by the mechanism described, then lateral bending will take place through the axis B–D Hence the concavity of the curve is directed anteriorly as well as laterally, producing the *kypho*scoliosis seen clinically

A simple model may be constructed to reproduce these conditions A set of ordinary wooden blocks (in this case, a child's building blocks) are taken to represent a series of vertebrae An upper and a lower corner of each is shaved down to represent vertebral wedging (Fig 8) Two vertical holes are drilled in each, as shown, to receive the cord which binds them together The cord should have slack enough to allow a little play between the blocks If the column of blocks is bent laterally toward the intact side, as shown in Figure 9, pure lateral deviation will occur If the column is bent toward the wedged side, anterolateral deviation occurs, the equivalent of a kyphoscoliosis (Fig 10)

ROTATION

If the wedged apposing surfaces are lubricated with soap to represent the slippery inter-

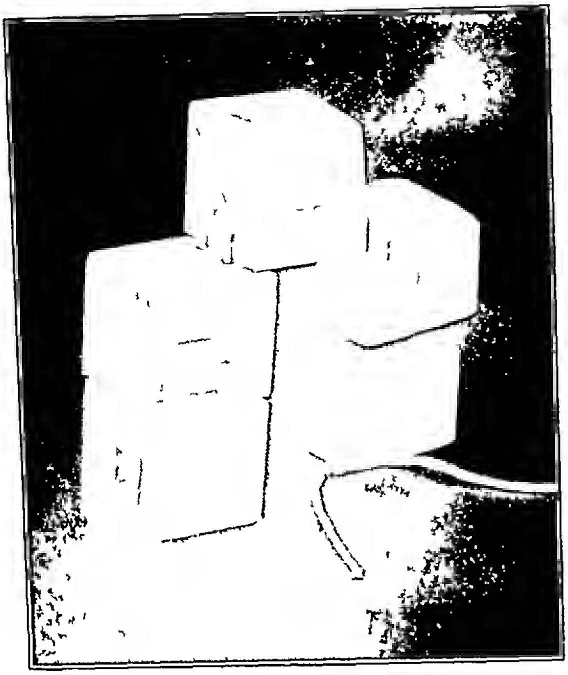

Fig 8
Construction of model

Fig 9
Lateral deviation to the intact side

Fig 10
Anterolateral deviation to the wedged side

Fig 11
Convex-side rotation with vertical compression

vertebral disc, and the column is compressed vertically (Fig 11), convex-side rotation appears, exactly as it is seen clinically The reason for this is immediately apparent A wedged vertebral body under compression acts exactly like a wedge and is squeezed out laterally when pressure is applied (Fig 12) This can be seen roentgenographically, especially in children, although in adult specimens the overlapped vertebrae may build up a bony buttress to meet the adjacent overhang That this is a passive process is in accord with Steindler's observation that "no muscle can shift a vertebral body in horizontal direction"

Some of the rotation occurs by the actual rotation of a vertebral body across the one adjacent (between the individual bodies), although this is limited by the surrounding

ligaments and especially by the limited excursion of the posterior joints Much of the rotation occurs by plastic torsional deformation of growth *within* the individual vertebrae, against the resistance of the posterior articulations The internal structure of the body follows accurately the lines of force occurring in a structure such as that shown in Figure 2 (The torsional deformation of the middle of the curve against the ends should also be taken into consideration) The bodies at the apex of the curve are subjected to internal plastic deformation, analogous to that seen when a grape is expelled from its skin The bodies at the upper and lower ends of the curve show deformation in response to the lines of force which are oblique to their vertical axes, leading to the formation of the "oblique" or "quadrilateral" vertebrae found in this location

This plastic deformation ceases when epiphyseal growth ceases Hence one may postulate that it is produced by an oblique or sideways deflection of growth by the pressure forces at the epiphyseal region It is suggested that the slow deformation in slipping of the capital femoral epiphysis is produced similarly The deflection of the newly formed juxta-epiphyseal bone may be considered as analogous to the deflection of streams of water, issuing from pipes at right angles to a moving stream In both cases, the deflection is in the direction of the sideways force Appleton has reported similar pressure-induced deformations of growing bone in the experimental animal Further observations on this mechanism will be reported by the author in a subsequent article

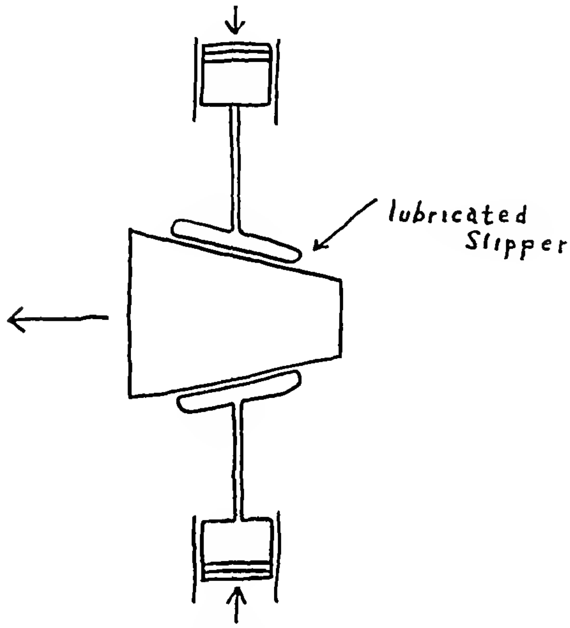

FIG 12
Action of a wedge under compression

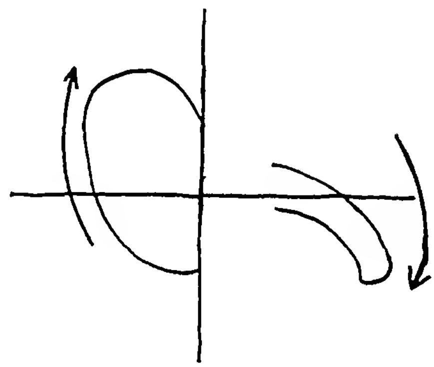

FIG 13
Rotation in an apical vertebra, as seen from above

In a diagrammatic representation of a wedged apical vertebra as seen from above* (Fig 13), the body is squeezed over or deflected to the convex side of the spinal curvature It is known that no muscles act upon the body to distort it in this fashion, and that this passive plastic deformation in the direction of increasing rotation about the facets is the result of the wedge action described here However, the spinous process is also deviated,—toward the *concave* side of the curvature This cannot be the result of wedging, since it is not wedged and is not in contact with any other spinous process The deformation must be the result of forces in soft tissue, since only soft tissues are in contact with the spinous process Moreover, this deformation is in the direction of increasing rotation, hence there must be some muscular or ligamentous component of rotation

In Figure 14, the dots represent the tips of the spinous processes in a scoliotic spine The line connecting these dots represents the interspinous and supraspinous ligaments

* The transverse processes are not shown, as their deformation has been described previously by Steindler

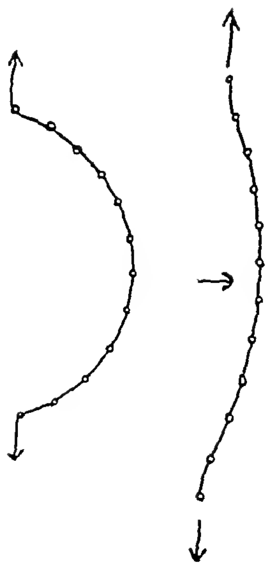

FIG. 14

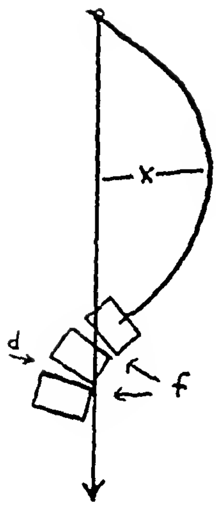

FIG. 15

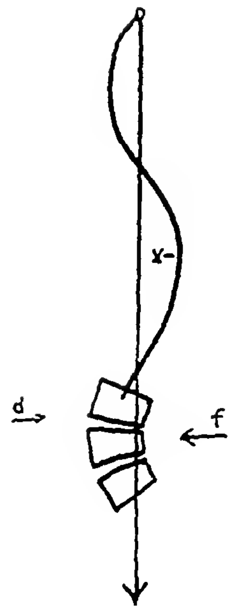

FIG. 16

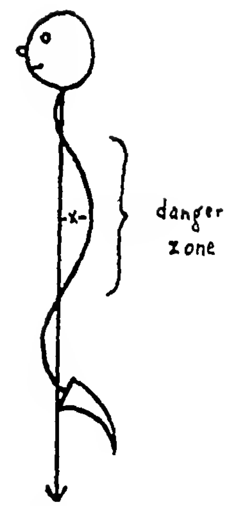

FIG. 17

Fig. 14 Extension of a curved line
Fig. 15 Recurvature of the ends of a curve
Fig. 16 Fig. 15 after development of compensatory curves
Fig. 17 Anteroposterior curves of a normal spine

When these ligaments are put under tension (in a kyphoscoliosis), they tend to straighten out the curve, as shown. The long spinal muscles on each side of these ligaments will also tend to straighten out under tension. Thus the spinous processes in the middle of the curve will be deviated to the concavity of the curve, while the bodies remain in their former position, resulting in convex-side rotation. The muscle contribution to rotation is similar to the action of the rubber bands in the model described by Rogers. These were tense (and hence yielded convex-side rotation) in both flexion and extension of the model. Lovett', in 1905, found that side bending in excised spines was associated with convex-side rotation (same direction as in Figure 13) only in flexion, when the interspinous ligaments are tense.

It is this mechanism which accounts for the small amount of rotation seen in un wedged post-thoracoplasty scoliosis, but the importance of this mechanism in the production of rotation is relatively small, compared to the importance of wedging (Figs. 3 and 4).

The Development of Compensatory Curves

In scoliosis with a single major curve (Fig. 15), the ends of the curvature are bent back or recurved, due to the attempt of the patient to level off his pelvis and head. The vertebral bodies in this region are unwedged at first, hence these compensatory curves are functional, not structural.

It will be noted in a roentgenogram of a scoliotic spine that, as the spine begins to recurve, the discs begin to be compressed on the *opposite* side of the bodies and on the concave side of the new curve (Fig. 15, *d* and *f*). Pressure is thus falling on the corners of the bodies at *f*, distraction is present at *d*. This may lead to inhibition of growth at *f* with wedging of the vertebra and conversion of the "functional" compensatory curve into a "structural" curve.

The first or main curve need not be structural (wedged) in order to initiate the development of a functional counter curve. Many purely functional curves have functional counter curves which have developed concurrently. They have never deviated sufficiently from the weight-bearing line to cause wedging, and these well-compensated curves are usually static and do not progress to a structural scoliosis.

Steindler noted that, when structural scoliosis is arrested spontaneously, it is by the

natural development of compensatory curves. His compensation treatment is designed to aid the development of this process, which, of course, is the principal means of correction in all methods of treatment, since, as far as is known, the wedged apical vertebrae cannot be corrected. He stated: "That a spine well compensated by the development of a triple scoliosis, well aligned, will maintain its balance under favorable conditions is a matter of almost daily experience."

Figure 16 demonstrates why this is successful. A factor determining the amount of weight acting upon the corner of the vertebral body, as shown earlier, is the x distance. Compensation diminishes this distance and thus diminishes the compression of the epiphysis. Haas showed that growth was resumed when compression had been removed, hence with both sides of the epiphysis growing, the deformity does not progress.

Fig. 18

Enlarged view of apex of curve in Fig. 3

Risser mentioned the relationship between pressure and epiphyseal growth ("Hueter-Volkmann's epiphyseal pressure rule"), and used this principle to induce the formation of structural compensatory curves. He noted that, by forcibly recurving the ends of the scoliotic curve in a plaster jacket for a prolonged period of time, he could produce wedging of the vertebrae (at point *f* in Figure 16). He suggested that this was due to inhibition of growth by the pressure produced by the plaster jacket. The rationale for the value of the flexion position recommended by Risser will shortly become obvious.

One more point remains to be made. Figure 17 shows the anteroposterior curves of the normal spine. In the cervical and lumbar regions, the normal lordosis relieves the anterior portions of these regions (the bodies) from part of the superincumbent weight, throwing it more upon the posterior articular facets. This explains why the region from approximately the second thoracic to the second lumbar vertebra is the danger zone for the development of wedging. The cervical vertebrae are practically never wedged. The lumbar vertebrae are only partially protected, due to the greater superincumbent weight they carry (and due also to the forward displacement of the line of gravity in low thoracic kyphoscoliosis). They are sufficiently protected, however, so that they rarely become wedged, despite the frequency of functional curves due to inequality of limb length. Steindler quotes Schulthess's statistics, which show that the vast majority of curves have their apices between the third thoracic and the second lumbar vertebrae. Of this number, 11.7 per cent. occur at the first and second lumbar, the predisposing condition being the habitual attitude of flat back. "If, on the other hand, he succeeds in compensating his anteroposterior curve by developing a round hollow back, then his spine is comparatively safe against lateral deviation."

Hence, when the x distance (Fig. 17) is increased by habitual postural kyphosis, excessive weight is thrown upon the thoracic vertebral bodies. This is more evenly distributed, and never of the order of magnitude of the excessive compression in scoliosis. It is suggested that the epiphyseal rings, which appear at about the fourteenth year of

life, are compressed by this mechanism (see the effect of pressure in Figure 18), leading to "vertebral epiphysitis" or adolescent kyphosis, which the author considers to be a pressure-induced growth disturbance Steindler stated that Mau, describing the microscopic findings in vertebral epiphysitis, found no real ossification process

Another possible factor, that of increased superincumbent weight, was probably operating in the cases described by Virchow, who, according to Steindler, "found this condition in the Australian negroes, who from their early adolescence are in the habit of carrying weights upon their shoulders, or of pulling carts with forward flexed trunk"

DISCUSSION

It has been shown how a functional, non-wedged curve can progress into a fixed structural scoliosis Although a discussion of the etiology of the preceding functional curve is not within the scope of this paper, it may be assumed that the initiating cause of the functional curve, in some cases at least, may continue to contribute to the structural scoliosis which follows

Functional curves may be divided into two groups In one group there is a known causative factor, in the other, the cause is considered obscure These latter are usually labeled as idiopathic or habitual, they are extremely frequent, almost universal, and the multitudinous discussions of the etiological significance in their causation of sitting and standing posture, right-handedness, attachment of the diaphragm, preponderance of right thoracic curves, et cetera, are well known

In the first group, the initiating cause of the displacement is clear In this group fall the congenital anomalies, and those following poliomyelitis and empyema Congenital anomalies, such as hemivertebrae or oblique fifth lumbar vertebra in the lower lumbar region, do not usually lead to structural scoliosis, for the reasons outlined earlier In the thoracic region they may or may not progress, depending upon whether the compensating curves are acute enough to keep the distance from the weight-bearing line within the critical limit Poliomyelitis with its attendant muscle changes can produce a functional curve This is quite likely to progress, because the natural process of compensation is handicapped by muscle abnormalities, and so structural scoliosis is relatively frequent It is also apt to be severe when it becomes structural, because of the difficulty of establishing compensatory curves and because of the lack of muscle support on the convex side, which decreases the effective y distance There is probably no direct effect on the epiphysis from the poliomyelitic infection Were this so, a bilateral complete trunk paralysis would have a bilateral epiphyseal arrest with resultant severe kyphosis This does not occur

Empyema and thoracoplasty furnish an obvious mechanism for curvatures The differences in types of scoliosis developing after onset in childhood and adult life have been pointed out It is not strictly true that there is *no* wedging in curves beginning after the age of sixteen Some slight wedging may occur, due to arrest of growth of the rings, up to the age of twenty-five, when they unite with the rest of the vertebral body (Fig 18)

Whatever the cause of the functional curve, as soon as it has produced a deviation exceeding a certain critical value, the factors described in this paper come into play and the spine has embarked on the course of epiphyseal compression and structural scoliosis It is possible that such factors as rapidity of growth, heredity, and sex, and pathological processes, such as rickets, may modify the quantitative relationship between pressure and growth arrest

Obviously the best treatment is prevention, by correcting postural deviations, whether in the anteroposterior or the lateral plane, or both, before they progress to structural changes In a severe curve, plaster jackets and braces cannot completely relieve the epiphysis of the pressure induced by the superincumbent weight, tremendously multiplied as it is by the mechanical arrangement which obtains Recumbency, of course, removes the superincumbent weight completely A combination of these two methods (jackets plus

recumbency) would seem to offer the better prospect of successful conservative treatment

SUMMARY

1 The vertebral deformation of structural scoliosis can be explained by an asymmetrical disturbance of epiphyseal growth by pressure

2 "Vertebral epiphysitis" is a related lesion

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DISCUSSION

Dr Henry F Ullrich, Baltimore, Maryland Aside from agreeing on the spelling of the word "scoliosis", I believe that those of us who treat curvatures agree on but one other point,—that is, that scoliosis is a deformity of the growth period and, therefore, is intimately related to epiphyseal growth and activity Beyond that point, especially in the field of mechanics of the deformity, one is apt to wander into theoretical considerations, draw conclusions from them, and apply those conclusions to the living, growing spine, where they are not strictly applicable because other factors are present In dealing with this complex deformity, let us always keep in mind the fundamental differences between facts and opinions, and let us remember that opinions may become facts if substantiated by correct, accurate, and controlled observation

That there is tremendous asymmetrical pressure on epiphyseal plates cannot be denied, but there must be other factors to provoke this asymmetrical pull and to initiate this unilateral increase in compression force We do not know how much pressure is required to produce the effects that Dr Arkin has described Concerning rotation, I believe the spine does not behave as a square cross section, or even as a cylindrical cross section, but that the neutral axis of each vertebral body is different at each level, and, because of this, different mechanical forces act on different vertebrae For example, the forces acting on the first thoracic vertebra are entirely different from the forces acting on the third, fourth, fifth, or sixth thoracic vertebra

The spine, I believe, rotates in order to accommodate itself in the easiest manner to its acquired position Hence, rotation is a function of curvature and varies directly with it

Most of us now have abandoned the concept that a compensatory curve, no matter how severe, will straighten, once the deforming tilt has been removed by jacket correction or other means Especially in a growing individual, this occurs up to the ability of the spine to straighten within the limits of the structural changes present, and little, if any, beyond that After the growth period has passed, balance and correction—but not beyond the point of the spine included in a fusion area—are factors to keep in mind, in order that a reverse deformity may not be produced

I sincerely hope that Dr Arkin's essay will provoke more sound thinking regarding scoliosis, especially with respect to the primary factors involved in producing curves of unknown etiology

Dr Joseph C Risser, Pasadena, California Dr Arkin's paper is very timely He refers to a law of bone growth that is recognized infrequently In 1862, after work and dissection on the foot, Hueter concluded that wherever there was not direct apposition of joint cartilaginous surfaces in the growing individual, there was an increase in the growth of epiphyseal bone Volkmann, in 1882, clarified that law and applied it

to scoliosis The importance of Hueter-Volkmann's epiphyseal pressure rule in growing bone is illustrated by slides

The first slide shows a tuberculous spine in a nine-year-old boy, with destruction in the inferior portion of the first lumbar vertebra The typical tuberculous destruction, with hazy translucence over the entire area and narrowing of the intervertebral space, may be seen Fusion was accomplished over the diseased area and included one joint above Two years later, the disease was arrested by virtue of immobilization, leaving a residual bone defect in the inferior portion of the first lumbar vertebra Three years later, after continued vertebral growth, roentgenograms showed that the vertebral body just below the area of destruction had grown upward into the defect, illustrating the contention made by Hueter

The same principle is illustrated in another nine-year-old boy, who had a thoracic curvature of the spine The thoracic area had been fused previously, leaving a residual thoracic curve without compensation in the lumbar area, and causing a list in the direction of the thoracic curve In order to overcome this deformity, the spine was bent markedly against the thoracic curve, creating a sharp compensatory curve in the thoracolumbar area, just below the thoracic fusion This permitted a marked separation of the vertebral bodies at the thoracolumbar area, creating a compensatory convexity on this side Fusion was then carried down to include two vertebrae in this compensatory curve Four years later, with rapid vertebral growth, the vertebral bodies had built up into the space created by the bending of the thoracolumbar curve, again illustrating Hueter-Volkmann's epiphyseal pressure rule

In another nine-year-old boy, who had not only a lateral curve but also some wedging of the thoracic vertebrae, fusion was carried throughout the thoracic area following correction of his lateral curvature Four years later, there was a very solid fusion and the wedged vertebrae had actually built up, so that, instead of being wedged anteriorly, the vertebrae were relatively normal in shape The slides and illustrations show the effect of pressure and release of pressure upon joint cartilaginous surfaces or upon rapidly growing epiphyseal areas Such epiphyseal areas are not only vulnerable to pressure, but become more vulnerable when there is any lack of integrity of the growing bone, as illustrated by epiphyseal fragmentation

A girl of thirteen years had a lateral curvature with the apex at the first lumbar vertebra In the lateral view, marked epiphyseal fragmentation and wedging were noted at the first lumbar and the adjacent vertebrae This young lady had a low basal-metabolic rate, which suggests a lack of essential bone-building materials Therefore, we see that not only are mechanical factors involved in the control of growth of bone, but also factors influencing bone physiology

Apical vertebral rotation is a concomitant part of lateral deviation Rotation is dependent upon the relation of the segments or vertebral bodies in the spinal column In the lumbar region, contact between vertebral bodies at the posterior articulations is more eccentrically located than in the upper portions of the spine Because of this eccentric relationship, the lumbar vertebral bodies will rotate earlier In the thoracic spine, the contacts are less eccentrically placed and rotation, therefore, is a later development in lateral curvature The initial change in the upper thoracic area is manifested earlier in wedging than in rotation This was specifically mentioned by Dr Ullrich

It is important to determine the completion of vertebral growth, this cannot be ascertained by laws of averages, but must be determined physiologically for each individual The best physiological sign we have found is the development of the iliac apophysis This development apparently takes place about the time of completion of growth of the epiphyseal plate of the vertebral body It is difficult to determine the completion of growth of these vertebral plates, or epiphyseal plates of the vertebral bodies, but very easy to determine the development of the iliac apophysis Therefore, as a physiological sign, the development of the iliac apophysis is a reliable method of determining cessation of vertebral growth

This is shown clearly in a girl of fourteen (Slide) Ten years later, we notice the same amount of deformity (Slide) The growth of the iliac apophysis had been completed at the age of fourteen, indicating cessation of vertebral growth and a static condition of the lateral curvature

Dr Alvin M Arkin (closing) I think Dr Risser, Dr Ullrich, and I all agree that the structural changes were due to growth arrest resulting from pressure

Dr Risser's apt illustration of the lumbar vertebrae, in which he produced wedging by a plaster cast, is very appropriate You will remember that the line of gravity usually protects these lumbar vertebrae if there is a lumbar lordosis, and I suggest this is the reason Dr Risser likes to use a flexion jacket, so that he can get the weight on these bodies, stop growth on one side and allow it on the other, and thereby produce the wedging

The rotation in the lumbar spine, free of wedge deformity, is slight compared to that found when wedging is present This is due to the action of the tight ligaments and muscles (not pathologically tight) Tension is normally present in the ligaments and muscles in the posterior regions of the spine These structures, under tension, cause rotation of the middle of the curve against its ends

THE PATHOLOGY OF NEURAL-ARCH DEFECTS

A DISSECTION STUDY

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In the literature, the etiology of spondyloschisis has been ascribed to divergent causes, but in particular to trauma. If the latter theory is held to be acceptable, then there are certain facts which must be reconciled with it,—such as the existence of multiple anomalies which involve not only the pars interarticularis, but also the lamina and the ligamentum flavum. In order to clarify this matter and to establish these facts, the following dissection study is presented.

Acute traumatic spondyloschisis (fractures through the partes interarticulares on both sides) do occur, and may occur in a normal spine free from anomalies. If diagnosis is made in such cases at the time of injury, and if suitable protection is provided, bony union results.

The specimen for this dissection study was obtained from the cadaver (No. C17) of a white male, forty-four years old. Roentgenographic studies had previously revealed bilateral defects in the neural arch of the fifth lumbar vertebra and a spondylolisthesis. That portion of the lower back where these lesions were located, and the associated structures—the last four presacral segments and the sacrum—were removed from the cadaver.

Following the removal of the overlying musculature, the elements of the posterior segments of each lumbar vertebra were exposed. These included the spinous processes, the laminae, the partes interarticulares, and the articulations between the articular processes (the intervertebral joints), together with their associated ligaments. All the laminae were then viewed as during a laminectomy or a spine fusion, and they appeared superficially to be of equal size and inclination. The isthmi or partes interarticulares (terms to be used interchangeably) of all the vertebrae except those of the fifth lumbar were at a somewhat deeper (or more anterior) level than were the laminae, and their inclinations were almost directly caudad-cephalad. The isthmi of the fifth lumbar were more prominent in comparison, being on a level with their respective laminae, and toward the cephalad direction they deviated laterally in a more oblique fashion. These isthmi appeared to be deformed, were more rounded, and were narrower in thickness than those of the vertebrae above. They were well encapsulated in a fibrous sheath which seemed to be a part of the ligamentum flavum, as well as continuous with the capsules of the intervertebral joints above and below.

Neural-Arch Defect on the Right Side

The outstanding finding was that accessory ligaments, not hypertrophy, were demonstrated in the ligamentum flavum.

The ligamentum flavum between the laminae of the fourth and fifth lumbar vertebrae on the right appeared to form a square (Fig. 1). In the medial upper quadrant, a modified round ligament arose separately from the surface. From thence it inclined obliquely and caudad, terminating in the medial aspect of the fibrous encapsulation of the defective isthmus. In the lateral upper quadrant, a separate fan-shaped ligament was seen, arising from its relatively wide base along the caudad margin of the lamina of the fourth vertebra; from there it converged to a thickened termination in the fibrous encapsulation of the isthmus, cephalad to the attachment of the other ligament (Fig. 2). The pattern of varia-

Fig 1

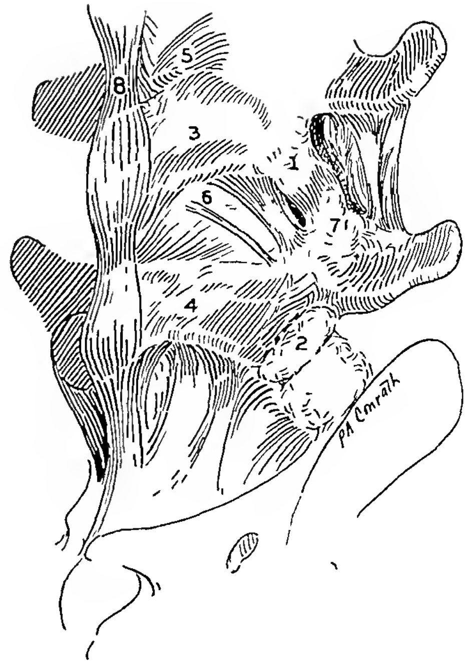

Fig 2

Fig 1 Sketch of the posterior oblique photograph shows the defective right pars interarticularis of the fifth lumbar vertebra Compare with right posterior oblique roentgenogram of same area (Fig 10)

1 Intervertebral joint cephalad to defect in pars interarticularis, formed by the inferior articulating facet of the fourth lumbar and the superior articulating facet of the fifth lumbar vertebra

2 Intervertebral joint caudad to the defect in the pars interarticularis, formed by the inferior articulating process of the fifth lumbar vertebra and the articulating process of the sacrum

3 The lamina of the fourth lumbar vertebra

4 The lamina of the fifth lumbar vertebra

5 The ligamentum flavum between the laminae of the third and fourth lumbar vertebrae

6 The ligamentum flavum between the laminae of the fourth and fifth lumbar vertebrae In the lateral upper quadrant, the fan-shaped ligament is evident Medial to *6*, a small plaque of bone was found in the substance of the ligament The round ligament, originating above *6*, was detached before the photograph was made

7 The defective right pars interarticularis of the fifth lumbar vertebra, ensheathed in its fibrous capsule which is continuous with the joint capsules above and below and with the fan-shaped and round ligaments

8 The supraspinous ligament

9 The normal right pars interarticularis of the fourth lumbar vertebra

Fig 2 Sketch of the round and fan-shaped ligaments of the ligamentum flavum, adjacent to the right defective pars interarticularis of the fifth lumbar vertebra

1 The intervertebral joint cephalad to the defective pars interarticularis

2 The intervertebral joint caudad to the defective pars interarticularis

3 The lamina of the fourth lumbar vertebra

4 The lamina of the fifth lumbar vertebra

5 The ligamentum flavum between the laminae of the third and fourth lumbar vertebrae

6 The ligamentum flavum between the laminae of the fourth and fifth lumbar vertebrae, showing the round and fan-shaped ligaments converging to the fibrous encapsulation of the defective pars (The sketch shows these attaching to the distal rather than to the proximal segment of the pars)

7 The defective pars interarticularis, ensheathed in a fibrous capsule

8 The supraspinous ligament

tion of this ligament was, therefore, not that of uniform thickening throughout (hypertrophy), but rather it was characterized by the presence of accessory ligaments arising from it

The fibrous sheath enclosed a cavity about the defective pars, which was separated from the joint cavity above by a fibrous septum

An incision fashioned a flap from the encapsulating sheath and its continuity with the joint capsules above and below (dotted line, Fig 1), this flap was reflected medially in the direction of the spinous processes (Fig 3) The articulating facets of the intervertebral

FIG. 3

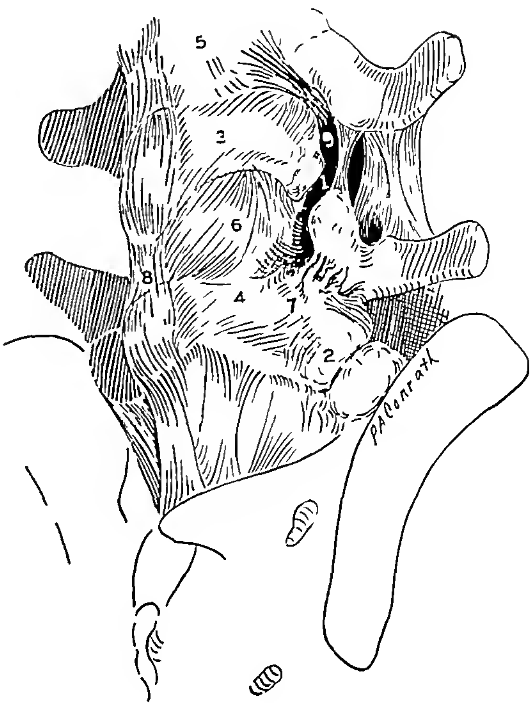

FIG. 4

Fig. 3. Sketch of the right posterior oblique photograph shows the fifth lumbar vertebra. The fibrous sheath has been reflected medially toward the spinous processes, exposing the defective pars.

1. The reflected fibrous sheath is held back with a pin, showing from above downward the interior or synovial lining of the capsule of the intervertebral joint, the orifice in the sheath between *1* and *8* and adjacent to *1*, and, just lateral to it, the fibrous septum which separates the joint space above from the space about the defective pars below. The latter space did not appear to have a synovial lining.

2. The intervertebral joint cephalad to the defective pars interarticularis. The sketch shows, not only a subluxation of the joint (*2*), but also separation, the latter improvised for the sake of clarity of detail.

3. The intervertebral joint caudad to the defective pars.

4. The lamina of the fourth lumbar vertebra.

5. The lamina of the fifth lumbar vertebra.

6. The ligamentum flavum between the laminae of the third and fourth lumbar vertebrae.

7. The ligamentum flavum between the laminae of the fourth and fifth lumbar vertebrae.

8. The defective pars interarticularis. The defect is seen at the cephalad extent of the pars, and the three connecting ligaments are evident,—the cephalad, the middle, and the caudad.

9. The supraspinous ligament.

Fig. 4. Sketch of the right posterior oblique photograph following removal of the fibrous sheath about the defect, including the capsules of the intervertebral joints above and below, as well as the fan-shaped ligament.

1. The intervertebral joint cephalad to the defective pars shows marked amount of subluxation. (Again, the separation of joint surfaces is a convenience, assumed for the clarity of detail in sketching.)

2. The intervertebral joint caudad to the defective pars. There is normal approximation of the opposing facets.

3. The lamina of the fourth lumbar vertebra.

4. The lamina of the fifth lumbar vertebra.

5. The ligamentum flavum between the laminae of the third and fourth lumbar vertebrae.

6. The ligamentum flavum between the laminae of the fourth and fifth lumbar vertebrae, now denuded of fan-shaped and round ligaments.

7. The defective pars interarticularis of the fifth lumbar vertebra, showing the segments joined by the cephalad, middle, and caudad ligaments.

8. The supraspinous ligament.

9. The normal pars interarticularis of the fourth lumbar vertebra.

oint cephalad, and a fibrous septum between the joint cavity and the cavity surrounding he defective isthmus caudad, were thereby exposed. The synovial lining of the joint cavity resented shallow plications adjacent to its attachments, suggesting the possibility of ynovitis. The exposed intervertebral joint disclosed a marked subluxation, the superior rticulating facet of the fifth vertebra covering only the lower half of the inferior articulating facet of the fourth vertebra. A hypertrophic spur projected from the posterior aspect of the rim of the facet of the inferior articulating process of the fourth vertebra.

Fig 5

Fig 6

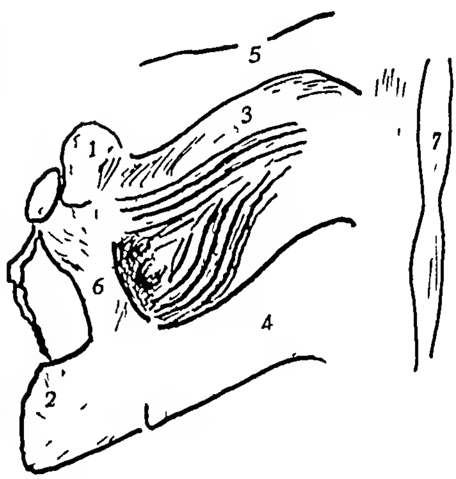

Fig 7

Fig 5 Photograph of the posterior aspect of the specimen at the termination of dissection study Apparently, there has been a partial developmental lumbarization of the first sacral segment and a sacralization of the first coccygeal segment

1 The intervertebral joint on the right, cephalad to the defective pars
2 The intervertebral joint on the right, caudad to the defective pars
3 The lamina of the fourth lumbar vertebra on the left
4 The lamina of the fifth lumbar on the left Note the abnormal conformation of the anterior cephalad extent of both laminae and their pseudo-articulations with the pedicles Between *4* and *7* on the left, the ligamentous attachment is shown, joining the lamina with the posterior aspect of the pedicle Note also the absence of a pars interarticularis on the left, between *4* and *7*
5 The normal pars interarticularis of the fourth lumbar vertebra on the right
6 The defective pars interarticularis of the fifth lumbar on the right
7 The pedicle of the fifth lumbar vertebra on the left

Fig 6 Sketch of the posterior oblique photograph of the laminar defect of the fifth lumbar on the left Compare with left posterior oblique roentgenogram of same area (Fig 12)

1 The intervertebral joint cephalad to the defect
2 The intervertebral joint caudad to the defect
3 The lamina of the fourth lumbar vertebra
4 The lamina of the fifth lumbar vertebra
5 The ligamentum flavum between the laminae of the third and fourth lumbar vertebrae

6. The ligamentum flavum between the laminae of the fourth and fifth lumbar vertebrae
7. The fibrous sheath at site of the pars interarticularis of the fifth lumbar vertebra
8. The supraspinous ligament
9. The normal pars interarticularis of the fourth lumbar vertebra

Fig. 7. Sketch of the ligamentum flavum between the fourth and fifth lumbar vertebrae on the left, showing linear patterns.
1. The intervertebral joint cephalad to the defect
2. The intervertebral joint caudad to the defect
3. The ligamentum flavum
4. The lamina of the fifth lumbar vertebra
5. The lamina of the fourth lumbar vertebra
6. The fibrous sheath of the defect
7. The supraspinous ligament

The fibrous septum separating the two cavities was reinforced along its posterior margin by an extension of the rounded portion of the fan-shaped ligament described previously. The latter traversed the fibrous encapsulation, extended tautly across the cavity as part of the fibrous septum, and was attached to the bone of the cephalad segment of the isthmus. The second round ligament, which was followed to the fibrous encapsulation, traversed this sheath, extended tautly across the cavity parallel to the ligament above, and was attached to bone immediately adjacent to it. Upon removal of the reflected flap *in toto* (Fig. 4), the fan-shaped ligament was found to be a continuous part of the encapsulating sheath. The defective isthmus, the articulating facets, and the ligamentum flavum were now exposed.

The defect in the right pars interarticularis was joined not by fibrocartilage, but by ligaments. Pseudo-articulation was found between the pedicle and the abnormal prolongation of the cephalad portion of the lamina; this was also joined by ligaments.

The defect was found at the upper end of the isthmus. The cephalad segment was 2 millimeters in length. The caudad or lower segment measured 1.2 centimeters. There was a 3-millimeter defect between the two bony segments. The length of both segments including the defect was 1.7 centimeters. By comparison, the length of the intact right isthmus of the fourth lumbar was 5 millimeters. The defect itself was not filled with fibrocartilage, but the junction of the two segments was well stabilized by fibrous ligaments. Three ligaments were present,—a cephalad, a middle, and a caudad. The cephalad and caudad ligaments appeared to be non-elastic, and they extended along the respective sides of the defect. (As noted, the defective isthmus was in an almost horizontal position.) The ligaments were intimately attached to both bone fragments. The cephalad ligament measured 3 millimeters in width, while the caudad one—a well-developed fibrous band—measured 1.8 centimeters in width. The middle ligament interposed between the ends of the fragments was of equal thickness, but was more flexible. It appeared to have been non-functional, as far as stress and strain are concerned. A microscopic section of this ligament revealed adult fibrous tissue without any evidence of cartilaginous or osteoid tissue.

Removal of the ligamentum flavum was undertaken next. Within the section immediately over the dura, the site traversed in seeking a ruptured nucleus pulposus, a small, thin, wafer-like plaque of bone was encountered. When the lateral extent of the ligamentum had been taken away, an abnormal conformation of the lamina appeared (Fig. 5). Its cephalad margin—that portion of the lamina between the base of the spinous process and the superior articulating process—extended horizontally to the pedicle to which its irregular edge (measuring 1.5 centimeters in width) was attached by intervening ligamentous tissue. This junction of the two was fixed beneath and was strongly stabilized by the wide caudad ligament of the adjacent defective isthmus described previously.

Neural-Arch Defect on the Left Side

The ligamentum flavum contained singular line patterns: the lateral half was divided into two leaflets; the superficial or posterior leaflet presented a round fibrous sheath along its lateral margin in place of the normal isthmus.

FIG 8

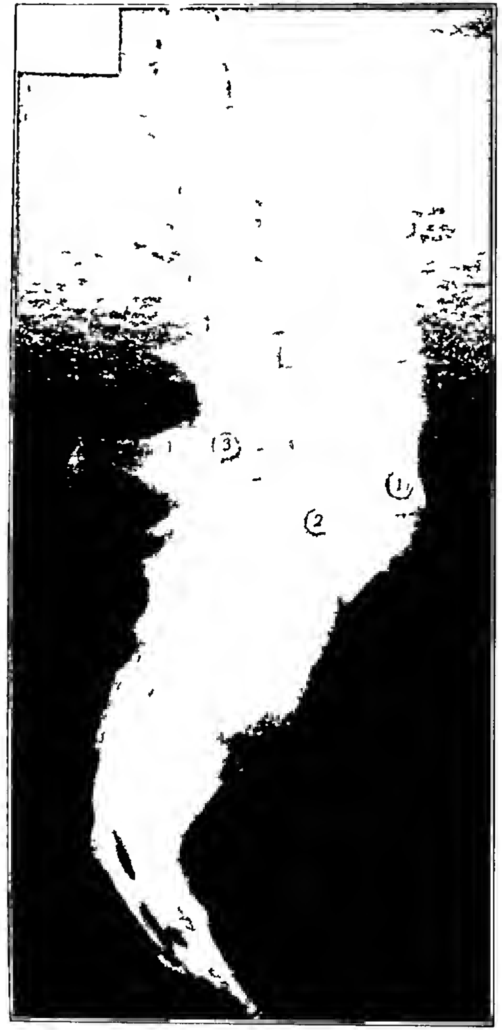

FIG 9

FIG 10

FIG 8 Anteroposterior roentgenogram
1 Spinous process in central alignment
2 The inferior articulating process of the fourth lumbar vertebra on the right
3 The superior articulating process of the fifth lumbar vertebra on the right The anteroposterior view shows to greatest advantage the subluxation of this joint
4 The shadow of the fifth lumbar partially imposed on the first sacral segment

Fig 9 Lateral roentgenogram

1 The body of the fifth lumbar vertebra, showing its anterior displacement on the sacrum, almost complete disappearance of the intervertebral disc beneath, and hypertrophic spurring of its anterior surface

2 The first sacral segment, showing reactive sclerosis of its posterior superior surface, and hypertrophic spurring of its anterior marginal aspect

3 The defect between the lamina and pedicle can be seen immediately above and to the right of *3* The contiguous spinous process shows slight posterior displacement with reference to that of the one above

Fig 10 Right posterior oblique roentgenogram (Film has been reversed)

1 The superior articulating process of the fourth lumbar vertebra is shown just to the right of *1*

2 The pars interarticularis of the fourth lumbar vertebra

3 The inferior articulating process of the fourth lumbar vertebra

4 The superior articulating process of the fifth lumbar vertebra

5 The defect in the pars interarticularis of the fifth is seen between *4* and *5*

6 The articulation between the inferior process of the fifth lumbar vertebra and sacrum

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Attention was then directed toward the dissection of the defect on the left side The fibrous sheath over the defective segment of the arch was much thinner than that encountered on the opposite side, and was more regular and direct in alignment (Fig 6) It formed a thin, tubelike structure, extending from the cephalad and lateral aspects of the lamina of the fourth vertebra, adjacent to the lower intervertebral joint, to that portion of the pedicle immediately posterior and caudad to the intervertebral joint above Palpation revealed a softness and pliability in its mid-section On casual examination, the ligamentum flavum of the involved interspace appeared as normal as those in the interspaces above However, closer examination revealed two line patterns in its fibers, which did not constitute separate ligaments One linear pattern arose from the medial upper quadrant of the membrane, extended directly laterally, and terminated at the junction of the rounded fibrous sheath with the superior articulating process, in the lateral upper quadrant (Fig 7) The other linear pattern, originating in the same focal area in the medial upper quadrant of the membrane, swept in an obliquely curved pattern downward and lateral to the outer lower quandrant, affixing itself to the base of the rounded fibrous sheath at its point of attachment to the lamina

Incisions to outline the flap over the defect were made in the same manner as on the opposite side In cutting through the fibrous sheath, which was presumed to enclose a defective isthmus, only two longitudinal flaps were produced rather than the opening into an enclosure of bony isthmic defects The fibrous sheath was not an encapsulating structure at all, but rather a solid, round modification of the more superficial of the two layers constituting the lateral half of the ligamentum flavum The incision had merely divided the full thickness into two longitudinal flaps Further dissection to expose the joint above did not show any degree of subluxation The synovial lining was not remarkable The facet edges showed minimal hypertrophic irregularities

Immediately deep to the divided rounded fibrous sheath was a cavity, indicating the absence of the pars interarticularis The deep layer of the lateral half of the ligamentum flavum covered the floor of the cavity, which also included the posterior aspect of the pedicle and the projecting portion of the lamina The superficial or posterior layer measured 5 millimeters, and the deep or anterior layer, 3 millimeters Microscopic section of the posterior layer revealed areas of calcified cartilage After the ligamentum flavum had been completely removed, the same type of attempted articulation of the abnormal cephalad prolongation of the lamina with the pedicle was seen, similar to that described on the right side, and again free of any fibrocartilage (Fig 5) The ligament deep or caudad to this junction was more rudimentary and elastic in appearance than was that on the right side, and measured one centimeter in width

ROENTGENOGRAPHIC FINDINGS

The defect in the neural arch is quite obvious in the lateral view (Fig 9) The intervertebral disc between the displaced body of the fifth vertebra and the sacrum has almost disappeared The condensation of bone and spur formation are evident along the opposing

FIG. 11

FIG. 12

Fig. 11. Intervertebral joints and associated processes, outlined on left posterior oblique roentgenogram. (Film has been reversed.)
1. Superior articulating process of the third lumbar vertebra with shadow of transverse process superimposed resembling eye and bill of a duck.
2. The pars interarticularis (isthmus) of the third lumbar vertebra, resembling neck.
3. The inferior articulating process of the third lumbar vertebra.

Fig. 12. Left posterior oblique roentgenogram. (Film has been reversed.)
1. The superior articulating process of the fourth lumbar vertebra.
2. The pars interarticularis of the fourth lumbar vertebra.
3. The inferior articulating process of the fourth lumbar vertebra.
4. The superior articulating process of the fifth lumbar vertebra.
5. Between *4* and *5* is the defect created by the absence of the pars interarticularis of the fifth vertebra on this side.

surfaces of the sacrum. In the right posterior oblique view (Fig. 10), the line of defect is faintly seen across the involved isthmus. There is no evidence of reactive sclerosis at the site of breach in continuity, no sclerosis is evident in the related intervertebral joints above and below the defect. Galluccio pointed out the "bow-tie" appearance of the pars with its associated articular processes, as a means of orientation in studying oblique views. In the author's experience, orientation is simpler by visualizing the shadow of the superior articulating process with its superimposed transverse process as the bill and eye of a duck, the isthmus being the neck. If the neck is discontinuous or broken, it may be concluded that a defect in the pars is present (Fig. 11). The left posterior oblique view (Fig. 12) is significant in this respect, since no neck is seen on the "duck" of the fifth vertebra, indicating that the isthmus is absent. In the presence of this relatively great defect of bone, the facets of the intervertebral joints above and below are free from subluxation (as shown in the

anteroposterior view, Figure 8, and in the dissection of the specimen) There is evidence of reactive sclerosis and hypertrophic lipping of the inferior articular process of the fifth vertebra on this side, where it hooks over the articulating facet of the sacrum

CONCLUSIONS

In discussing the relative significance of neural-arch defects and split spinous processes (bifid spines), Willis stated "When the defect destroys the integrity of that portion of the bony arch between the vertebral body and the inferior articular processes as in the case of a bilaterally separate neural arch the condition is much more serious Here we have the anchorage of the spine depending merely upon a fibrocartilaginous union with ligamentous and muscular support" Again, "Rupture of the synchondrosis [defect] is more serious than the ligamentous injury which accompanies it The separated bone ends are covered with cartilaginous material and, therefore, show no tendency to reunite" In this particular specimen, the defect in the isthmus on the right was united not by fibrocartilage, but by unusually strong fibrous ligaments, and was ensheathed in a fibrous capsule The isthmus on the left was completely absent, and there was no evidence of fibrocartilaginous replacement The pseudo-articulations between the pedicles, and the abnormal prolongations of the cephalad portions of the laminae, were effected by ligaments and not by cartilage

Findings in this specimen were (a) the complete absence of an isthmus on one side, and, on the other side, a defective isthmus strongly fixed by ligaments and three times the length of the normal isthmus above, (b) the abnormal conformations of the laminae and their pseudo-articulations with the pedicles, (c) the structural variations noted in the ligamentum flavum on each side, and (d) the associated presence of a partial developmental lumbarization of the first sacral segment and a sacralization of the first coccygeal segment

NOTE The author wishes to acknowledge his gratitude to Dr Mildred Trotter, Professor of Gross Anatomy, Washington University School of Medicine, for her kindness in making this specimen available

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NUTRIENT ARTERIES OF THE VERTEBRAL BODIES*

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The venous plexus in and around the vertebrae have been described frequently, but little information is available concerning the course of arterial supply to the vertebral bodies. An effort has, therefore, been made to determine this.

Patten has described the formation of the vascular system by coalescence of blood pools throughout the embryo, and the formation of the aorta by fusion of primitive dorsal aortae which develop from arteries arching from the heart around each side of the pharynx

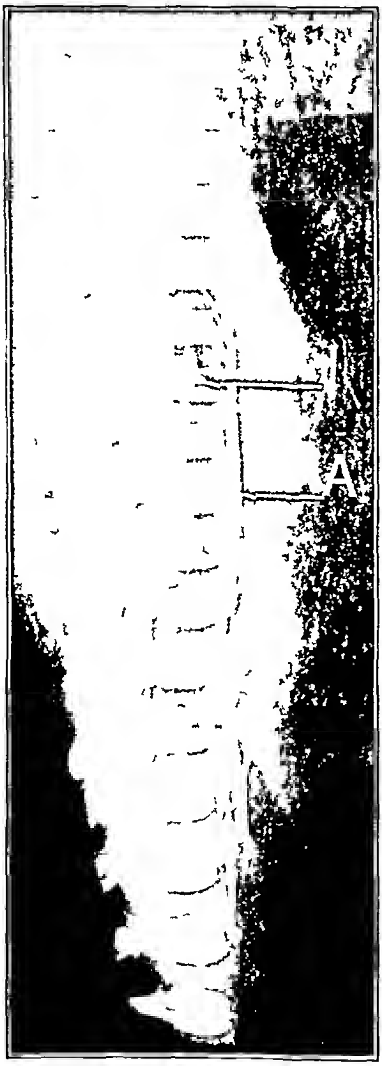

FIG. 1-A

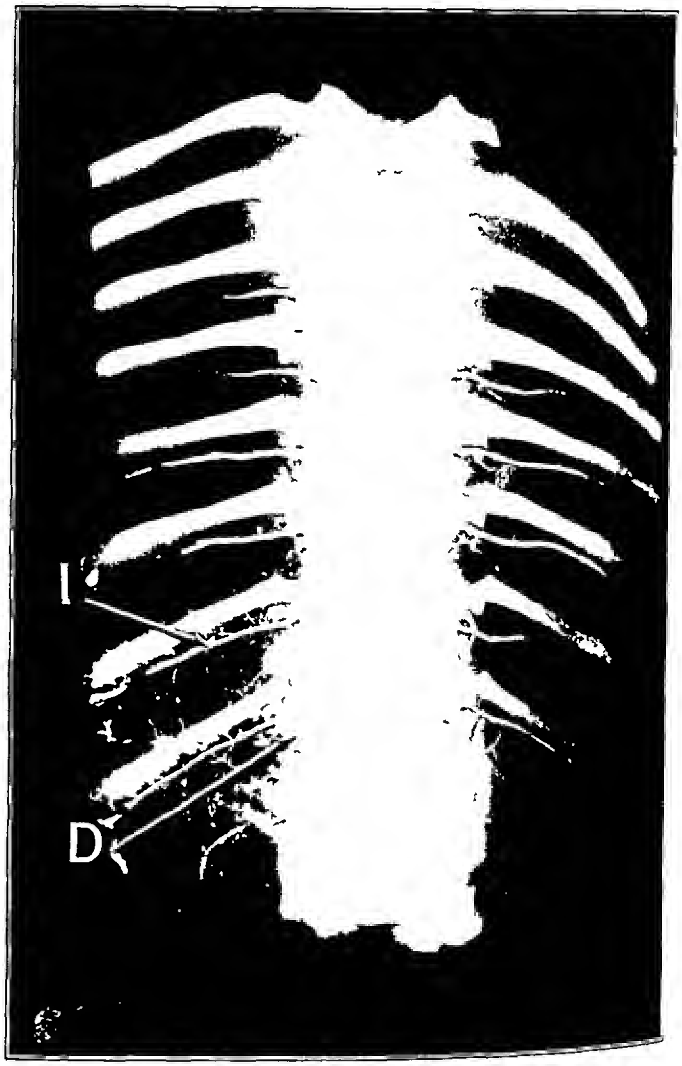

FIG. 1-B

Fig. 1-A. Lateral roentgenogram of a full-term foetal spinal column with opaque vascular injection of the aorta. *A* indicates the aorta, *I*, the intercostal artery. Note notching of anterior surfaces of the vertebral bodies and lesser density of the bodies in their mid-portions. The longitudinal anastomosis of arteries in the neural canal is well shown.

Fig. 1-B. Anteroposterior view of the same column after removal of the aorta. *I* shows the intercostal artery, *D*, the dorsal division of the artery. Note anastomosis of the intercostal arteries and incomplete ossification of the cartilaginous neural ring.

* Part of an address to the Alumni of the Hospital for Ruptured and Crippled and the Hospital for Special Surgery, New York City, October 29, 1948.

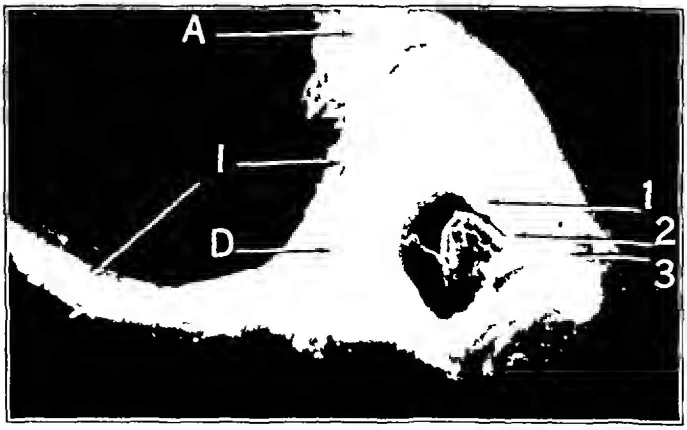

Fig 2-A

Fig 2-A Vertical view of one of the thoracic vertebrae *A* shows the aorta, *I*, the intercostal artery, *D*, the dorsal division *1*, *2*, and *3* are the first, second, and third branches of the dorsal division Note the many fine arteries penetrating the periosteum and the perichondrium

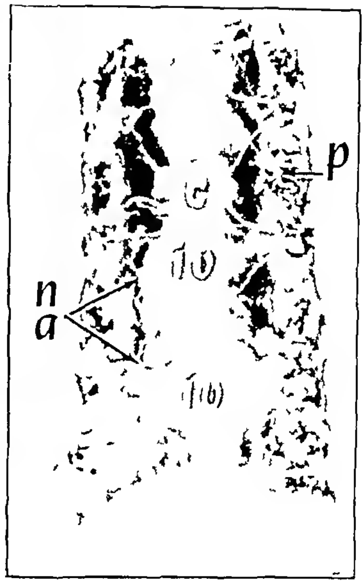

Fig 2-B

Fig 2-B Photograph of the posterior surface of the same vertebrae after removal of the neural arches *p* is the amputated pedicle stump, *c*, the vertebral centrum, *iv*, the intervertebral-disc area (*c* and *iv* are covered by the posterior spinal ligament), *na*, the nutrient arteries, the first branches of the dorsal division of an intercostal or lumbar artery

Each of the primitive aortae, before they fuse, gives off branches which mark the spinal column into segments After fusion, the paired segmental vessels, which become intercostal and lumbar arteries, extend dorsally from the aorta and cross the middle of the lateral surfaces of the vertebral bodies, one on each side The larger element of each runs laterally, anterior to the lower border of the ribs and the transverse processes, to supply the thoracic and abdominal walls A large branch is given off in the trough formed by the vertebral bodies and transverse processes It traverses the intervertebral foramen and divides into three terminal branches, one to the posterior surfaces of the two adjacent vertebral bodies, another to the spinal cord and its membranes, reaching the cord by way of the ligamentum denticulatum, and the third to the posterior vertebral processes and surrounding soft structures (Figs 1-A, 1-B, and 2-A)

The branches to the cord anastomose freely with the anterior and posterior spinal arteries which lie on the respective surfaces of the cord, extending from within the skull to the end of the cord Thus far, this vascular supply of the vertebrae is described in most texts of anatomy

It was formerly taught that the principal blood supply of the vertebral body entered through foramina on its anterior surface, the fovea centralis More recently, a nutrient artery has been described, entering the posterior surface

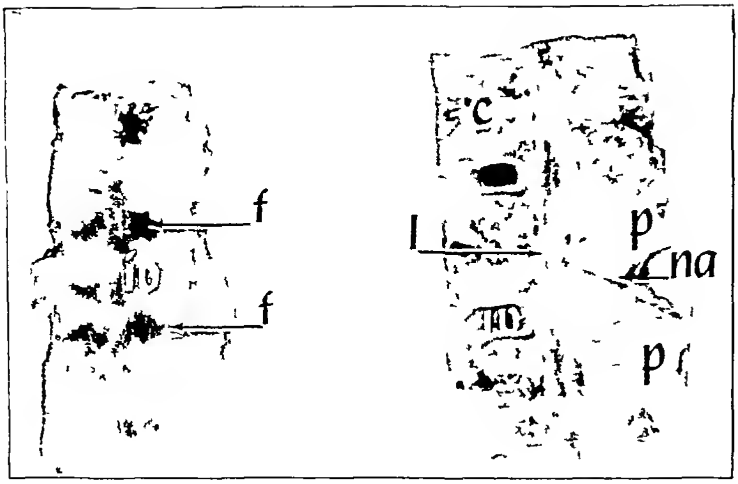

Fig 3-A

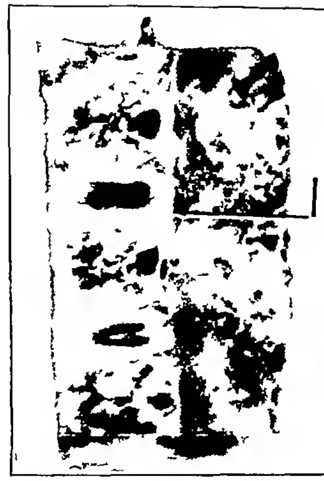

Fig 3-B

Fig 3-A Shown at left is a photograph of the posterior surface of three lumbar vertebrae, with the neural arches and posterior spinal ligament removed

At right is a similar specimen, split sagittally *f* indicates foramen for entrance of the nutrient arteries, *iv*, intervertebral disc, *c*, centrum, *l*, posterior spinal ligament, *p*, pedicle stump, *na*, nutrient arteries, entering the neural canal between the pedicles and disappearing under the ligament to reappear in the cavernous bone of the centrum

Fig 3-B Similar to Fig 3-A (right view), enlarged to show the cavernous ossification of the centrum, radiating from the center

portion lagging behind It is this layer of delayed ossification that gives the spool-shaped appearance in lateral roentgenograms of embryonic vertebrae The notch shown by roentgenograms on the anterior surface of the vertebral body (Fig 1-A), sometimes referred to as the fovea centralis, is due to relative lag in calcification of the cartilaginous centrum, not to the entrance of nutrient arteries The foramina seen on the anterior surface of the centra are exits for veins, not entrances for arteries

The nutrient arteries enter the posterior foramina from a layer of loose areolar tissue beneath the posterior spinal ligament, which bridges the concave posterior surfaces of the bones, being attached only at their upper and lower borders It is thickened in the mid line and weak laterally, where the vessels perforate it It does not fuse with the annulus of the intervertebral discs as completely as does the anterior ligament (Figs 3-A and 3 B)

Considerable importance has been ascribed by Schmorl, Beadle, and other writers to the radiating corrugations that are found on the surfaces of young vertebral bodies when the epiphyseal plates have been stripped off These, however, are found on the diaphyseal ends of all growing long bones and represent the usual waves of growth along the vascular tree A leg of lamb, a femur of a young pig, or a fowl's femur shows a similar concentric gear appearance when stripped of its epiphyseal plates

Blood-borne infections of bones are most apt to become localized in the end arteries of newly formed bone, where the vessels are easily thrombosed and the tissue is less resistant They occur, therefore, in the subepiphyseal ends of the vertebral bodies, as they do in other bones that grow from their ends

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CHANGES IN ELASTIC ADIPOSE TISSUE *

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The fatty tissues of the body vary in firmness according to their supportive function Soft adipose tissue forms an almost continuous layer beneath the skin, surrounds viscera, and fills cavities throughout the body[10] Here the fat cells are enmeshed in a loose fibrous-tissue network with a large amount of tissue fluid Gersh and Still, in studies on the rat, showed that blood vessels and lymphatics form a rich network throughout the adipose tissue This tissue can be distorted readily, and it slowly resumes its original shape as a result of the pressure of tissue fluid and the elasticity of the muscles or other structures beneath Soft adipose tissue should not be looked upon as supportive, but as packing material for the body It serves as subcutaneous insulation and as a readily available source of nutrition (Fig 1)

At the other extreme, with many gradations of firmness, is elastic adipose tissue (Fig 2) This is supportive tissue, and merits the attention of orthopaedic surgeons Schaffer observed that elastic adipose tissue sometimes takes over the function of cartilage and is is resistant to pressure In certain regions—the heels, the finger tips, the thenar and hypothenar eminences, the ischial tuberosity, and the prepatellar fat pads—there are firm deposits of fat[4], sometimes called pressure areas In these locations, nature has adapted the available tissues to withstand sudden impacts or prolonged pressure The architecture of the fibrous tissue is arranged to compress and bind the fat cells firmly Elastic adipose tissue from these locations resumes its original shape as soon as the excessive pressure has been removed (Figs 3-A and 3-B)

Tietze, in 1921, made the first detailed report on the special structure of elastic adipose tissue In the fat pad beneath the heel, he described dense strands of fibrous tissue, enclosing circular or cone-shaped septa The septa contained elastic fibrous tissue and closely packed fat cells An exhaustive study of the architecture of elastic adipose tissue was made by Blechschmidt, in 1933 His material came almost entirely from the calcaneal fat pad of the human embryo, since only in early life did he find the architectural pattern undistorted Both Tietze and Blechschmidt found fibrous-tissue strands, firmly attached to the undersurface of the calcaneus and extending to the subcutaneous tissues These tissues were usually in the form of a letter U, with the open end of the U pointing toward the calcaneus

In serial sections studied by Blechschmidt, the strands of fibrous tissue outlined chambers filled with fat cells The chambers were supported by transverse and diagonal elastic-tissue fibers There was a spiral arrangement of fibrous tissue among the fat cells, extending from the subcutaneous tissue to the calcaneus The fat was removed from these chambers with difficulty Firm attachments between the strands of fibrous tissue aided in resisting torsion (Fig 4) A somewhat looser arrangement of fibrous tissue in elastic adipose tissue is seen in other parts of the body It is thin over the palmar surface of the hand Over the volar surface of the terminal phalanges the elastic adipose tissue is less firm than that of the heel, but is similar in structure[5] A thick, but rather soft, elastic adipose tissue is present over the glutaeus maximus, which becomes firmer as it approaches the ischial tuberosity Almost as firm as that of the heel is the infrapatellar fat pad

All of these areas of elastic adipose tissue are present at birth, none develop in postnatal life under the stimulus of pressure In portions of the body unprotected by elastic adipose tissue, which are subjected to prolonged and constant pressure, one observes pressure necrosis If the pressure is intermittent, an adventitious bursa appears[6] While

* Read at the Joint Meeting of The American Orthopaedic Association, The British Orthopaedic Association, and The Canadian Orthopaedic Association, Quebec, Canada, June 4, 1948

FIG 1

FIG 2

Fig 1 Subcutaneous adipose tissue (× 50), showing the loosely packed fat cells, and the meager fibrous stroma (Stained with hematoxylin and eosin plus azan)

Fig 2 Elastic adipose tissue (× 30) from the heel of a child of three, showing the fat cells tightly packed by the dense fibrous stroma which is part of a "U system" (Stained with hematoxylin and eosin plus azan)

elastic adipose tissue is constructed to withstand strain and pressure, it may be damaged by severe trauma and it shows gradual deterioration with age, under continued excessive pressure, it becomes hypertrophied at first [4] In cadavera, the areas of elastic adipose tissue are usually firm and elastic in the young, and thinner and softer in the aged The state of nutrition has little effect Observers, including Batty Shaw and Wells, have found that elastic adipose tissue is spared for a long time in the nutritional demands made upon fats in the body

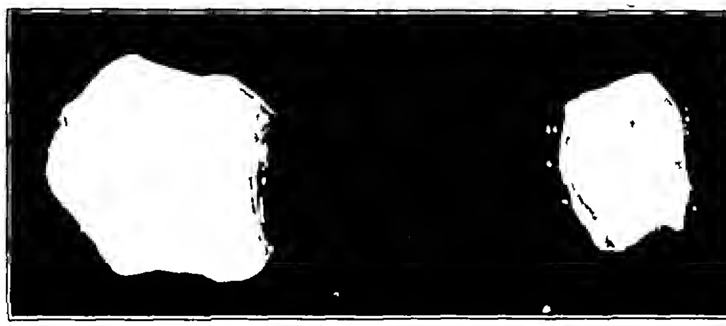

Fig 3-A Fig 3-B

Subcutaneous adipose tissue (Fig 3-A) and elastic adipose tissue (Fig 3-B) of equal bulk, compressed under a heavy glass plate There is little change in the elastic adipose tissue Ordinary adipose tissue is greatly distorted

Degenerative changes with increasing age are the most constant findings in elastic adipose tissue No regeneration has been observed Here there is a gradual loss of collagen, a decrease in the elastic fibrous tissue, and a decrease in water content [9] Distortion and rupture of the fibrous-tissue strands have been observed, with spilling of the fat cells (Fig 5) In childhood and early maturity, the undersurface of the calcaneus is smooth In the heels of elderly individuals, one usually finds evidence of loss of elasticity,—bony proliferation about the margins of the calcaneal tuberosity, roughened areas anterior to this, and bony ridges at the lateral margins of the calcaneal fat pad (Fig 6)

The common clinical finding associated with degenerative changes in the calcaneal fat pad is soreness under the heel This is sometimes found in the young after prolonged illness More persistent tenderness and pain is sometimes seen after marked increase in weight, or associated with serious disturbances in the alignment of the foot Such soreness is rarely found in children In about 5 per cent of adult patients seen in the clinic, tender areas were present in the posterior and inferior portions of the calcaneus Soreness and thickening were found on the medial and lateral edges of the heel These clinical findings are not restricted to human beings, cats and dogs, which have similar calcaneal fat pads, may show tenderness and a limp as they become old Pathological examination shows changes similar to those found in human elastic adipose tissue

Changes in elastic adipose tissue can be seen to a limited degree on roentgenographic examination Lateral roentgenograms of the heel were taken to show detail in the subjacent soft tissues The roentgenogram of the normal calcaneal fat pad shows a smooth undersurface of the calcaneus, beneath which is an area of dense fibrous tissue, about one-quarter inch thick Beyond this is elastic adipose tissue, varying in thickness, extending to the subcutaneous tissue of the heel In it, dense strands of fibrous tissue can be seen, extending vertically to the calcaneus These form the "U systems", described by Tietze and by Blechschmidt In normal individuals these strands are regular and parallel, and the chambers are similar in size In children and in young adults who had had no injury to the feet (Fig 7), the roentgenographic findings were normal

In patients who complain of soreness in the heel, the roentgenograms usually show bony proliferation at the medial and lateral edges of the fat pad, this has been interpreted by the roentgenologist as periostitis Bony irregularity about the calcaneal tuberosity is also commonly seen In the soft tissues, there is a less dense layer of elastic adipose tissue The fibrous strands are thinner, and are often irregular or broken in outline They are not parallel, and the septa enclosed by the "U systems" are irregular in shape and often confluent The sharp outlines seen in the young become increasingly distorted and blurred with age These changes can usually be found after the age of forty (Fig 8)

Fig 4

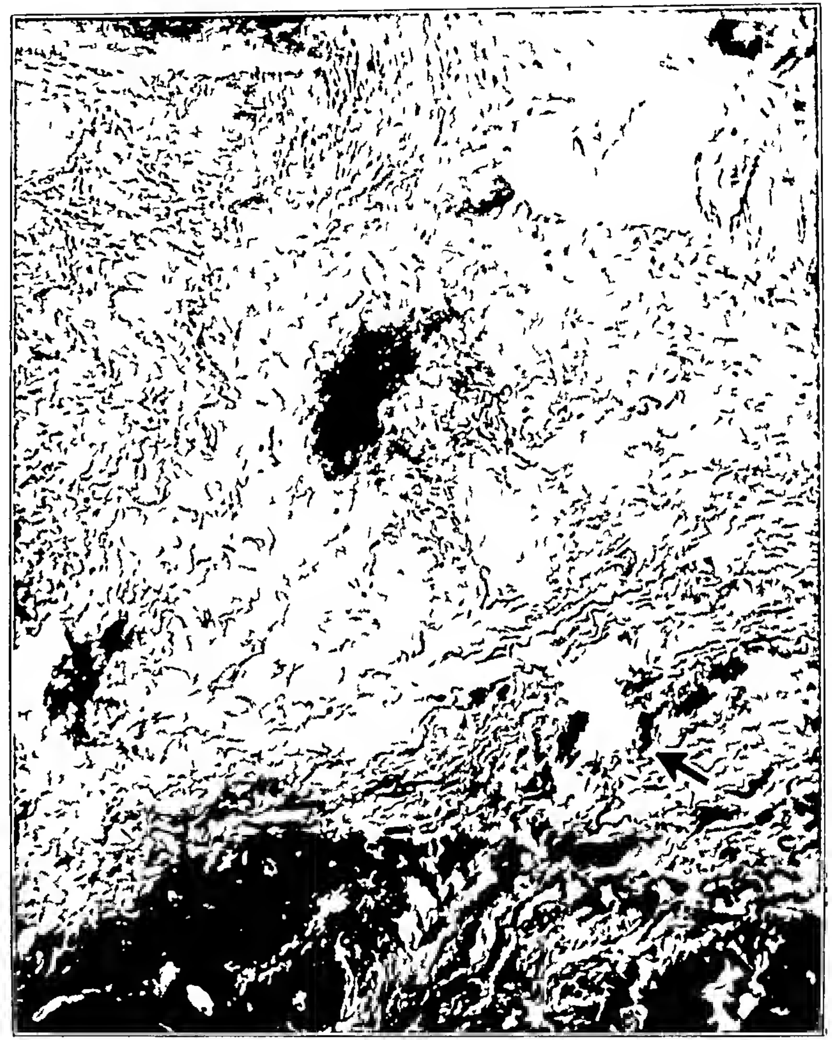

Fig 5

Fig 4 Normal elastic adipose tissue with normal fibrous-tissue stroma from the heel of a child of four (× 60) There are blood vessels and nerves in connective-tissue stroma (Masson stain)

Fig 5 Elastic adipose tissue (× 60) from the heel of a woman of sixty The connective-tissue stroma is less dense Breaks in the connective-tissue fibers can be seen at the lower right as well as fatty infiltration of fibrous stroma The fat cells are scattered (Masson stain)

Similar changes are also seen after marked obesity or severe trauma. In obese individuals, both young and old, often mild but easily discernible changes are seen in the soft tissues beneath the heel. A return to a normal roentgenographic appearance is rare, even after substantial reduction in weight and loss of soreness in the heel. In severe foot strain, if the mechanics of weight-bearing are restored, a normal roentgenographic picture is again found. These changes vary greatly from individual to individual, but they occur fairly constantly. In the aged, the changes increase, and no improvement is observed after prolonged avoidance of weight-bearing (Fig. 9).

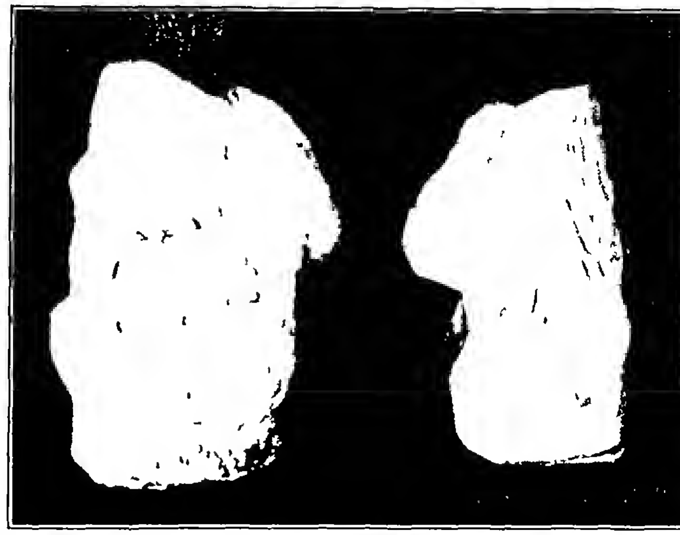

FIG. 6

Photograph of the tuberosity of the calcaneus. In specimen on the right, taken from a youth, the tuberosity and inferior surface of calcaneus are smooth. On the left, the heel of an elderly individual shows bony proliferation about the tuberosity and irregular inferior surface of calcaneus.

In severe trauma, extensive temporary changes are found in the elastic adipose tissue of the heel. Unfortunately, not many such observations with the normal side for comparison were available. After fracture of the calcaneus, a distortion of the architecture of the fat pad with flattening of the pad and rupture and irregularity of the "U systems" was usually found. With satisfactory healing of the fracture, these changes disappeared in from six to twelve months. In crushing injuries with severe comminution of the tuberosity of the calcaneus and lateral tearing and compression of the elastic adipose tissue the changes tended to be permanent. Only partial repair occurred, a new fat pad could not be produced. In evulsion of the fat pad, observed in two patients, no change was noted in the roentgenographic picture after resuture.

FIG. 7

Roentgenogram of calcaneal fat pad in child of six. The undersurface of the calcaneus is smooth. There is a thick pad of elastic adipose tissue. Many U-shaped fibrous bands can be seen.

These changes in the elastic adipose tissue of the heel were studied histologically in a few instances, from material obtained at operations and from autopsies. Elastic adipose tissue from the heels of cadavera was also examined. In all of these, the changes observed during clinical examination and in roentgenograms were due to a loss of collagen content and to fracture and distortion of the elastic-tissue strands. The best composite picture of

Fig 8

Fig 9

Fig 8 Roentgenogram of calcaneal fat pad in a woman of seventy-three There is bony proliferation about the tuberosity The elastic adipose tissue shows distortion of the U-shaped fibrous bands Relatively few fibers are seen, many of these are of the "U systems" and seem to have united The plantar vessels are calcified

Fig 9 Roentgenogram of calcaneal area in an obese man of thirty-six The inferior surface of the calcaneus is roughened and shows osseous proliferation Very few of the "U systems" can be seen

these changes was obtained from thin sections of elastic adipose tissue, stained lightly and examined under the dissecting microscope By this method, gross fracture and distortion of the fibrous tissue was observed The finer changes were confirmed by fixed sections, stained to show collagen or connective-tissue fibers

Few observations have been made of elastic adipose tissue in regions other than the heel In a few instances, study of the infrapatellar fat pad following operations, osteoarthritis, or trauma showed changes similar to those found at the heel An appraisal of the clinical importance of these changes in elastic adipose tissue would require a long period of study, both of clinical and of pathological material The data obtained so far from the study of the heel permit us to state that degeneration of elastic adipose tissue is often observed with advancing years Such degenerative changes are accompanied by stretching and tearing of the connective-tissue fibers which compress the fat cells With these changes, and presumably as a result of them, we find pain and burning under the heel after prolonged standing and walking Later there may be constant pain and disability Palpation of such a heel will show tenderness in the calcaneal fat pad Similar findings may be observed temporarily after obesity, after severe illnesses, and after trauma

Since these changes are, for the most part, degenerative, and since therapy for degenerative lesions is almost wholly palliative, our treatment of the changes in elastic adipose tissue is symptomatic In injuries to the calcaneal fat pad and in the milder degrees of degenerative change, a certain amount of repair may take place In severe degeneration, however, and in crushing injuries with involvement of the blood supply, the elastic adipose tissue remains incompetent permanently Rest and the avoidance of weight-bearing will give temporary alleviation Injections of procaine have given only transient improvement, measures to bring about improved alignment of the foot—shoes, supports, and corrective exercises—have been followed by more lasting relief Comfort can be obtained by forming a depression in the heel of the shoe, to avoid undue pressure on the calcaneal tuberosity A sponge-rubber pad fitted into the heel of the shoe is another useful measure There is no known means by which healing can be obtained in damaged elastic adipose tissue

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THE ETIOLOGY OF TROCHANTERIC FRACTURES OF THE FEMUR

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In an effort to determine the cause of fractures in the trochanteric portion of the femur in elderly people, the authors have studied 150 human femora, taken from the documented collection in the Hamann Museum. Thus the bony architecture in various age groups is correlated with the mechanics of this fracture. These facts have been substantiated by the production of trochanteric fractures in some of the bones by a specially designed machine. In addition, the mechanical forces involved have been determined from the evidence obtained in this study.

EXPERIMENTAL FINDINGS

Our material has been selected according to age, as follows: Specimens from a group of young individuals, ranging from twenty to thirty-five years, were compared with those from an older group, from sixty to eighty-five years. In addition, a group with trochanteric fractures were selected for comparison with the first two groups. Both femora, with a record of the sex, color, cause of death, and a brief history of the subject from which they had been obtained, were available for study. In the group with fractures, the unbroken mated femur was of great value.

All of the bones were macerated, according to a standard method used in the Department of Anatomy. Roentgenograms of the femora were taken, a standard technique being used to bring out the details of the architecture of the proximal end. A density gauge was pictured with each bone to judge uniformity of exposure.

Some of the bones were then fractured, by the use of a machine designed for the problem by the Case Institute of Technology (Fig. 2). This consisted of a pendulum, weighing fifty pounds, attached to a 60,000-pound Southwark-Emory Universal testing machine. The pendulum was suspended from the top of the machine, so that a dynamic force could be applied in a medial direction to the lateral portion of the upper end of the shaft of the femur. The femoral head was held in a lead form, intended to represent the acetabulum, and was padded with lead wool; the distal portion of the shaft was placed in a mold, packed with wet sand, firmly braced to the machine bed. A vertical load of from 100 to 125 pounds was applied to the head of the femur. The pendulum was then raised to various heights, and the force necessary to fracture the bone was calculated by regarding the pendulum as a free-falling body. The heights of six, nine, and twelve inches, corresponding to 300, 450, and 600 inch-pounds of energy, were found to produce the desired results. These figures were obtained by measuring the changes in vertical displacement of the center of gravity of the pendulum from its raised position to its location when in contact with the femur. Thus the bone was subjected throughout to forces simulating, to the best of the engineers' ability, those occurring in the living subject.

This mechanical treatment of the femur presented certain limitations of comparison with the living bone. For instance, the rubber pad over the steel pendulum was added in an attempt to simulate body tissue over the greater trochanter and upper portion of the shaft. The mold of wet sand and the lead acetabulum, plus the 100 pounds of vertical force, represented the ligaments and muscles attached to the femur and around the hip joint.

Repeated attempts to study the effects of torsion were unsuccessful, because of the brittle property of bone, which makes firm clamping along the shaft impractical. The only intracapsular fracture obtained with this machine resulted from incomplete fixation of

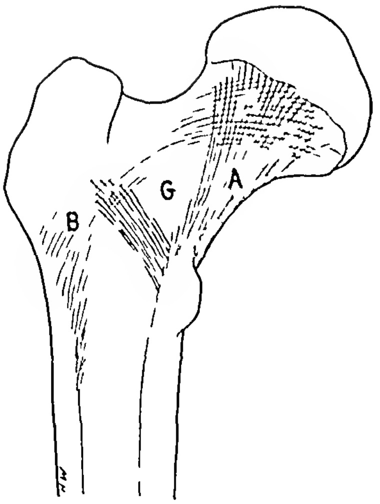

FIG. 1

Fig. 1: Diagram showing trabeculae of the upper portion of the femur.
Fig. 2: Diagram of testing machine with femur in position.

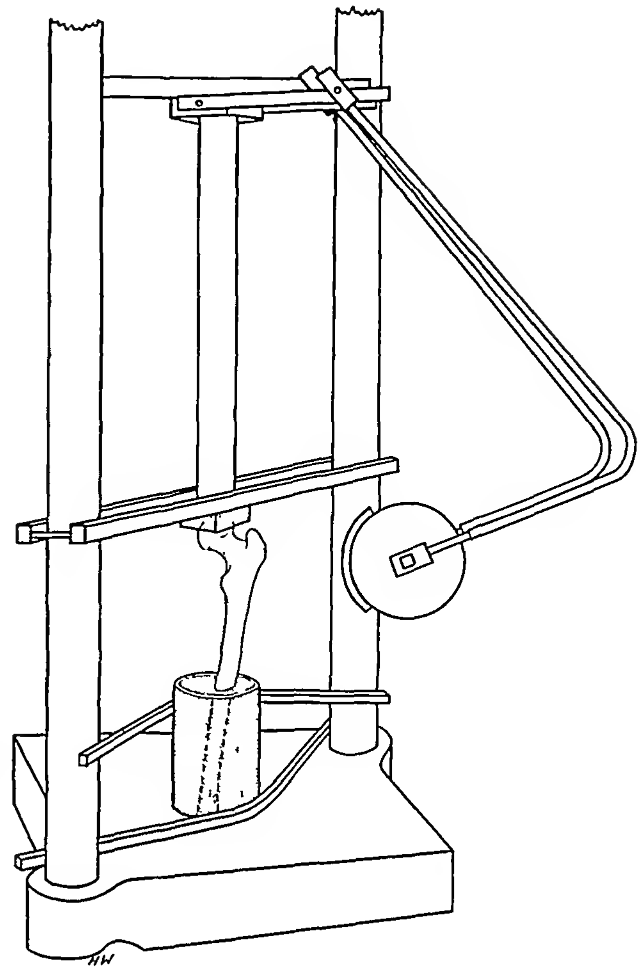

FIG. 2

the femur, so that the pendulum caused the bone to twist in the lead acetabulum and sandbox as it struck the lateral portion of the upper end of the shaft.

Finally the femora were covered with an aluminum undercoating and sprayed with "stresscoat". They were allowed to dry for twenty-four hours before forces were applied to the bones for pattern analysis. "Stresscoat" is a brittle lacquer that can be applied to the surface of an object and will crack when either static or dynamic loads are applied[2,4]. This property of the lacquer allows it to be calibrated for analysis of qualitative and quantitative stress. The pattern of the cracks reveals the direction of the force applied to the bone; the force direction is always perpendicular to the visible cracks. Only qualitative results were considered significant, since the quantitative calculations require a modulus of elasticity and reasonable uniformity of material, neither of which was attainable in the specimens studied. After the cracks had appeared, a red etching material was applied to preserve the pattern for subsequent photography.

RESULTS

The roentgenographic studies revealed a definite pattern of trabeculae, that tended to vary with the age of the individual.

In all specimens, the area known as Ward's triangle[10] can be outlined easily (Fig. 1,*G*). The most constant trabeculae are those which form the medial portion of the shaft and extend directly into the head (Fig. 1,*A*). The curved trabeculae on the lateral aspect of the shaft (Fig. 1,*B*) form the superior portion of the femoral neck and cross the medial trabeculae to terminate in the head. On the roentgenogram, the center of the neck between these two sets of trabeculae is seen as a less opaque triangle, with the apex pointing toward the head. The base is identified as the portion parallel with the intertrochanteric-ridge pattern.

In the young adult, the entire upper end of the femur presents a gray sheen, described by Todd, caused by the abundance of mineral deposited throughout the area (Fig. 3). As

a result of senility or debility, the gray sheen is lost and the trabeculae stand out against the less opaque background Careful examination reveals a breaking-up of the continuity of pattern, as if segments of the lamina were dissolved entirely This is seen earliest in line *B* (Fig 1) The lateral trabeculae are involved extensively before the medial group (Fig 1,*A*) show noticeable involvement Finally this column is also weakened, and the upper end of the femur becomes much less opaque to roentgen rays (Fig 4)

The group of femora containing the trochanteric fractures showed similar areas of demineralization when compared with the unbroken mate of the pair The fracture lines in the broken bones were found to go through this area Then a group of femora were fractured under controlled conditions at Case Mechanics Laboratory, and roentgenograms showed the similarity of the fracture lines to those described by Cleveland, Bosworth, and Thompson for their clinical group The femora classed as poorly mineralized always broke under dynamically applied loads of 300 inch-pounds or less Those femora in the well-mineralized group did not break or crack until a load of 600 inch-pounds had been applied, and in some instances they did not break under the highest loads (Table I)

For further analysis of the mechanics of this fracture, another group of femora were treated with "stresscoat", and the pattern of the cracks obtained under dynamic loads was studied

DISCUSSION

The frequency of fractures through the trochanteric region in elderly people is well known In addition, there is evidence of demineralization in this area in these cases This leads to the conclusion that the relative strength of the femur in the older person is less than that in a young adult The fracture line has been shown by roentgenography to extend through the trabeculae that are thinned out The specific weakness of the bone in this demineralized area has been ascertained by the production, under specific loads, of artificial trochanteric fractures A study of the bones after fracture, with the use of

FIG 3

Roentgenogram of femur that is well mineralized

FIG 4

Roentgenogram of femur that is poorly mineralized

"stresscoat", indicates that the starting point of the fractures is probably in this same area (Fig. 1,*B* and *G*).

The trabeculae actually exist as a single tubular structure with many interlacing members crossing the medullary portion. Each trabecula must take a definite part of the total load exerted on the femur. Thus forces applied are spread throughout the neck and down into the shaft, over the pathways set up by the trabeculae[3,5,6]. Two other factors present in roentgenographic studies are those of soft-tissue absorption, which has been eliminated by this study, and the degree of calcium absorption which is visible. Lachmann and Whelan have shown that calcium loss must be in the vicinity of 20 to 40 per cent before it is detectable by roentgenogram.

It was seen early in this work that the degree of osteoporosis in chronic disease, even in young adults, cannot be distinguished from that occurring in senility. Consequently, only bones taken from cadavera of individuals with a history of sudden death, without known chronic disease, were used for study.

Fig. 5

Photograph of femur treated with "stresscoat".

Several explanations have been offered for the strain paths shown in the "stresscoat" experiments (Fig. 5). The horizontal lines on the medial portion of the shaft and the underside of the neck may be tension cracks that occur in bending. This portion of the femur can be compared with the outer part of a simple beam. The cracks occurring around the greater trochanter at the impact point of the pendulum are indicative of the local condition only, and are not regarded as significantly related to the actual fracturing forces. However, the strain paths shown by the cracks running perpendicular to the intertrochanteric ridge indicate a tensile stress that is parallel to this ridge. All these patterns were evident in the several bones treated.

The cracks over the intertrochanteric ridge lie in the region of the bone that is shown by the roentgenographic studies to be most weak. We believe that this portion of the neck tends to become disrupted first, as determined by careful comparison of the fractured bones and of those which cracked, but did not entirely break apart. Several theories have been proposed to explain the condition, as indicated by the "stresscoat" pattern over this portion (Fig. 1,*B*). At first it was thought that this strain was evidence of Poisson's ratio[8], which is the relationship of strain in the Y direction to strain in the X direction. However, when a section of the shaft of the femur treated by "stresscoat" was subjected to static and dynamic compression, no strain paths appeared, thus showing no appreciable application of the Poisson ratio.

Another suggestion was that tensile stress might be created parallel to the intertrochanteric ridge, due to what can be called "arch action". This theory can be explained by the strain pattern that appears in a parabolic column. No evidence has been intro-

TABLE I

RELATION OF MINERALIZATION OF BONE TO LOAD REQUIRED TO PRODUCE FRACTURE

Bone No	Degree of Mineralization	Fracturing Force (*Inch-Pounds*)			Remarks
		300	450	600	
16	Good	0	0	0	No fracture
32	Good	0	0	+	Cracked only
14	Good	0	0	+	Cracked only
10	Good	0	0	+	Complete fracture
12	Moderate	0	0	+	Cracked only
17	Moderate	0	0	+	Cracked only
27	Moderate	0	0	+	Cracked only
11	Moderate	0	0	+	Complete fracture
15	Moderate	0	0	+	Complete fracture
23	Moderate	0	0	+	Complete fracture
30	Moderate	0	0	+	Complete fracture
19	Poor	+			Complete fracture
21	Poor	+			Complete fracture
25	Poor	+			Complete fracture

duced as yet to refute this statement Furthermore, when the fracture line is examined with this idea in mind, it appears possible that the intertrochanteric area is subjected to a tensile stress as explained by the "arch-action" theory, and that the actual break may be due to shear This is further substantiated, inasmuch as the edge of the cortex breaks at a 45-degree angle from the external to the internal surfaces This plane is at 45 degrees to the apparent direction of principal stress However, there is doubt that a material as brittle as bone will fail under shear

The fact that the fracture occurs in the lateral trabeculae first and then extends to the medial trabeculae is further substantiated by the behavior of this medial portion of the femur It is shown by the "stresscoat" to be subjected to an initial tensile stress, and yet it appears to fail because of a compression-type load This can be explained by a stress-reversal reaction, in which the arch of the neck tends to become straightened and elongated under the lateral load Since both ends of the femur are restrained, the trochanteric portion of the medial trabeculae can fracture only by compression

NOTE The assistance of Carl C Francis, M D, of the Department of Anatomy, is gratefully acknowledged

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THE SHORT FIRST METATARSAL

Its Incidence and Clinical Significance*

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The importance of shortness of the first metatarsal as a cause of disability of the fore part of the foot and of the longitudinal arch has been widely discussed since 1935, when Dudley Morton, in his admirable monograph, *The Human Foot*, first advanced this thesis. His idea seemed reasonable, and orthopaedic surgeons soon found a sufficient number of patients suffering from disabilities of the fore part of the foot associated with a short first metatarsal to lead many of them to accept this as the cause of the disability. In actual fact, the problem has never been submitted to adequate study, either by Morton or by others, and there is nothing in *The Human Foot* concerning the association of the short first metatarsal with foot disabilities which might not be the result of coincidence.

Difficulties in the management of foot problems in the Canadian Army during the recent War necessitated an extensive study of these problems by the Royal Canadian Army Medical Corps. The findings of this Canadian Army Foot Survey in respect to the short first metatarsal are of considerable interest and importance, the more so since they do not support Morton's hypothesis.

Morton's Thesis

It is Morton's contention that shortness of the first metatarsal causes disturbances in the transmission of weight and thrust forces through the fore part of the foot in the following manner:

1. If the first metatarsal is shorter than the second, it carries less than its normal share of weight, since its shortness prevents its head from reaching the ground as readily as does that of the longer second metatarsal. The bulk of the weight load transmitted through the fore part of the foot is shifted from the first metatarsal to the second, or to the second and third metatarsals.

2. The altered transmission of weight is manifested by (a) calluses beneath the heads of the second or the second and third metatarsals, and (b) roentgenographic evidence of thickening of the shaft of the second metatarsal in response to the increased stress to which it is subjected.

3. In an attempt to make the head of the first metatarsal reach the ground and bear its share of the weight, the fore part of the foot is pronated. This distorts the mid-tarsal joint and produces strain of the longitudinal arch.

Morton also contends that the same disturbances of weight distribution through the fore part of the foot occur:

1. When there is hypermobility of the first metatarsal segment as compared with the second. When this exists, weight-bearing displaces upward the head of the first metatarsal more easily than the second, which, in consequence, must transmit the greater proportion of the weight.

2. When the sesamoids of the hallux are placed more posteriorly than normal. This, in effect, is the same as a short first metatarsal, since the sesamoids provide the effective weight-bearing point of the hallux.

According to Morton, therefore, a short first metatarsal or hypermobility of the first metatarsal segment or posterior displacement of the sesamoids can be the source of foot disability, first, in the fore part of the foot, where it causes calluses beneath the

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 26, 1948.

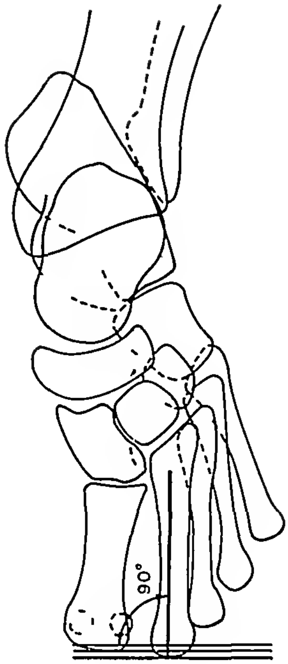

FIG. 1-A

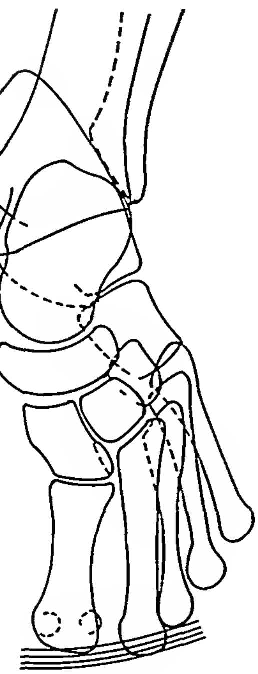

FIG. 1-B

FIGS. 1-A and 1-B

Comparison of the Canadian Army Foot Survey method of measurement with Morton's method. Shows the variation which may occur in Morton's method of measurement, dependent upon the amount of varus of the metatarsals. Tracings are from the same roentgenogram and are exactly similar. On the left, by Morton's method, the first metatarsal is shorter than the second by 1 millimeter. This measurement changes with the varus or valgus position of the metatarsals. On the right, by Survey method of measurement, the first metatarsal is shorter than the second by 6 millimeters. This measurement is not changed significantly by the position of the metatarsals.

head of the second metatarsal, falling of the transverse arch, and pronation of the fore part of the foot, and, second, in the longitudinal arch, which is subjected to undue strain by attempts to compensate for the diminished weight borne on the head of the first metatarsal. In *The Human Foot*, Morton stated that shortness of the first metatarsal is but occasionally the cause of disability, and then only in adult life. Nonetheless, it has been widely assumed that the presence of this anomaly inevitably tends to cause foot disablement, because of the disturbance in the transmission of weight and thrust stresses through the fore part of the foot. This we have found to be incorrect,—at any rate, for an unselected group of adult males, ranging in age from eighteen to thirty-five years.

CANADIAN ARMY FOOT SURVEY

The Foot Survey of the Canadian Army was designed to determine the incidence of all important foot defects among young adult males presenting themselves for army enlistment, and to assess the effect of these defects upon foot function by observation of the type and degree of disablement which developed during military training. At the enlistment center, 3,619 men were examined by precise methods. Of these, it was possible to follow 1,391 during their military training and to determine the functional capacity of their feet. From such observations, important conclusions have been drawn in respect to the alterations in function which result from foot defects and abnormalities, including shortness of the first metatarsal.

METHODS OF STUDY

Study of the short first metatarsal by the Canadian Army Foot Survey was conducted as follows:

Length of the First Metatarsal

The relation of the length of the first metatarsal to that of the second was determined by measurement from a standardized dorsiplantar roentgenogram of the foot. No other record permits accurate determination of the relative length of the first and second metatarsals. The special roentgenographic technique provided exactly comparable roentgenograms, showing all the bones of the foot with equal clarity from the posterior end of the calcaneus to the tips of the distal phalanges. Measurement of the distance from the posterior end of the calcaneus to the head of the first metatarsal and to the head of the second metatarsal gave precise information as to their relative length. This method of measurement is the most accurate, as is recognized by Morton, since it provides the

TABLE I

LENGTH OF FIRST METATARSAL AS RELATED TO LENGTH OF SECOND

Measurement of Difference (*Millimeters*)	Number of Cases
− 12	1
− 11	2
− 10	14
− 9	20
− 8	47
− 7	51
− 6	156
− 5	212
− 4	467
− 3	556
− 2	798
− 1	554
0	1,596
+ 1	463
+ 2	814
+ 3	459
+ 4	554
+ 5	194
+ 6	120
+ 7	49
+ 8	30
+ 9	4
+ 10	6
	7,167

Minus sign (−) means first metatarsal shorter than second, plus sign (+) means first metatarsal longer than second

information which is essential,—namely, the distance between the posterior point of support of the foot (tuber calcanei) and the anterior points of support (heads of first and second metatarsals) In ordinary roentgenograms it is not feasible to make this measurement, since the posterior end of the calcaneus cannot be visualized through the superimposed shadow of the tibia This difficulty has been overcome by the roentgenographic technique adopted for the Canadian Army Foot Survey

The method adopted by Morton for determining the length of the first metatarsal in relation to the second (the position of the most anterior portion of the head of the first metatarsal in relation to a line tangent to the head and at right angles to the axis of the second metatarsal) is open to considerable error, depending upon the position of the metatarsals in respect to varus and valgus (Figs 1-A and 1-B)

Distribution of Weight upon the Sole of the Foot

Since there is no accurate or simple means of measuring in pounds or kilograms the distribution of weight upon the sole of the foot, it was necessary to resort to two indirect methods of assessment,—(1) foot-printing and (2) clinical examination

Foot-Printing

By the use of rubber mats surfaced with ridges at three different levels, it was possible to obtain footprints which recorded clearly variations in pressure between one area of the foot and another Such mats print most where there is most pressure, and least where there is least pressure Areas of localized increase in weight-bearing are clearly indicated by local intensification of the imprint (Fig 6-B)

Clinical Evidence of Excess Weight-Bearing

The sole of the foot registers faithfully the weight it carries by the response of the skin to this stimulus. The greater the weight carried by a given area of skin, the thicker does its epidermis become. If weight is concentrated in a small area, the epidermal thickening is so great and so sharply defined that it becomes a callus which presses into the underlying dermis and causes pain. The skin upon the sole of the foot, therefore, becomes a record of the relative amount of weight borne by each part of the foot. Clinical observation permits us to read this record and to observe where most weight has been carried.

Functional Capacity

Of the men examined at the time of enlistment by the methods outlined, 1,391 were re-examined during their military training to observe the functional capacity of their feet. It was possible thus to correlate the findings of the enlistment examinations relating to structure with the functional performance of these feet under the stress of military training.

We have, therefore, accurate observations upon 3,619 pairs of feet, from which to determine the incidence of a short first metatarsal and of abnormal localized areas of weight-bearing (callus), and further observations upon the functional capacity of 1,391 pairs of these feet from which to determine the effect, if any, of this anomaly upon function.*

FINDINGS OF THE SURVEY IN RESPECT TO THE SHORT FIRST METATARSAL

Incidence of Short First Metatarsal

Figure 2 illustrates graphically the length of the first metatarsal relative to the second in 7,167 individual feet. (Because of frequent asymmetry, the feet have been measured and recorded separately, not in pairs.) Table I gives the data from which Figure 2 was compiled. It can be seen that:

In 2,878 feet the first metatarsal was *shorter* than the second by 1 millimeter or more.
In 2,693 feet the first metatarsal was *longer* than the second by 1 millimeter or more.
In 1,596 feet the first and second metatarsals were of *equal length* (within 1 millimeter).

These figures demonstrate that shortness of the first metatarsal is common, but so also is overlength of this bone. The most common state is equality of length between first and second metatarsals (1,596 cases or 22 per cent.). The majority of the remaining cases are within a few millimeters of equality, suggesting that this represents the normal for most feet.

If we arrange the measurements with respect to individual soldiers, we find that in 1,282 men the first metatarsals were shorter than the second, and in 2,337 men the first and second metatarsals were either of equal length or the first metatarsals were longer than the second.

Incidence of Local Excess Weight-Bearing

Study of the footprints and clinical examination of the sole of the foot revealed eighty-six and one-half pairs of feet which presented evidence of localized pressure. In the problem of the short first metatarsal, however, we are concerned only with excess pressure borne by the heads of the second or second and third, or sometimes the third and fourth metatarsals. Only thirty-five pairs of feet among the 3,619 examined showed evidence of excess pressure in these situations. In the remaining fifty-one and one-half pairs, the points of localized pressure were distributed widely in other parts of the foot.

Localized pressure under the heads of the second, third, and fourth metatarsal

* Details of the technique for the roentgenograms, the methods of measuring the length of the first and second metatarsals on the roentgenograms, and the method of obtaining footprints are omitted from this paper, since they already have been fully described[1].

was by no means limited to those feet which had short first metatarsals Indeed, evidence of disturbed weight-bearing was nearly as frequent in feet in which the first metatarsal was equal to or longer than the second as it was in feet with short first metatarsals The findings are summarized in Table II

Association of Short First Metatarsal with Pes Planus

Morton's contention that shortness of the first metatarsal induces pronation of the fore part of the foot and depression of the longitudinal arch makes a study of this association important It is possible to correlate the two factors from the data of the Foot Survey, and this has been done for several relationships In all of these studies, there is no greater incidence of pes planus or of pronation of the foot when the first metatarsal is short than when it is long We have been unable to find any evidence that the short first metatarsal causes pes planus, pronation of the foot, or longitudinal-arch symptoms

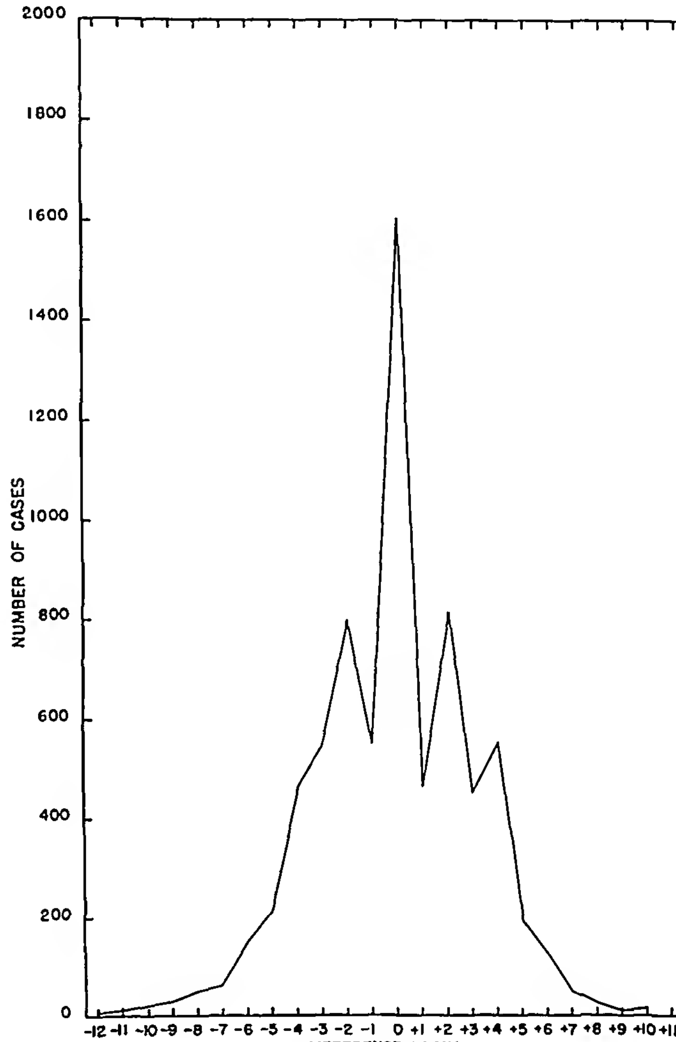

FIG 2

Length of first metatarsal relative to length of second, obtained from measurement of standardized roentgenograms of 7,187 feet Minus sign (—) means first metatarsal shorter than second, plus sign (+) means first longer than second (See Table I and Figure 1-B)

Functional Capacity in Relation to Short First Metatarsal

Observation of these soldiers and study of the foot problems which developed during their training did not disclose any evidence that shortness of the first metatarsal is a cause of foot symptoms during strenuous activity Such foot symptoms as did occur during training were attributable to other causes This is not to say that calluses beneath the heads of the metatarsals do not exist in soldiers and do not cause symptoms They do, but the evidence that these are due to a short first metatarsal is lacking, as indicated previously

The vast majority of soldiers with measurable shortness of the first metatarsal had no symptoms related to the condition and presented no evidence of disturbance of weight distribution The lack of symptoms when the metatarsal is short was sometimes very striking Two examples are illustrated, one in Figures 3-A, 3-B, and 3-C and the other in Figures 4-A and 4-B Both had very short first metatarsals and the soles of the feet were free from callus or other defects The men were also free from symptoms

There are many variations in the manner in which feet are used, which can act as compensatory mechanisms of considerable efficiency One such which could easily com-

Fig 3-A

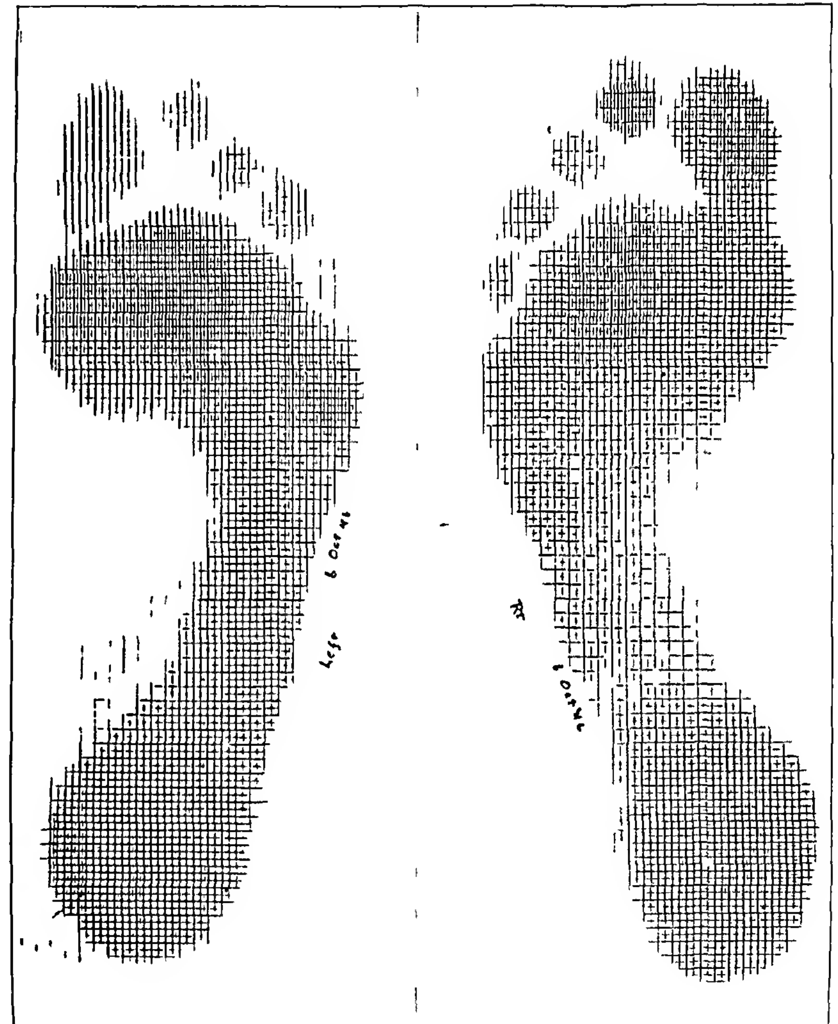

Fig 3-B

Fig. 3-A Roentgenograms of short first metatarsal There was no localized pressure under metatarsal heads no thickening of the second metatarsal, and no symptoms A characteristic example of the large group of individuals who suffer no disability and no disturbance of function from shortness of the first metatarsal
Figs 3-B Footprints of the same feet No clinical evidence of callus is seen and no sign of localized pressure under heads of metatarsals

pensate for any diminution in the support normally provided by the head of the first metatarsal is increased use of the flexor hallucis muscle The keen observer will often detect evidence of the use of the great toe in walking, and the mark of this increased use is callus on its plantar surface If shortness of the first metatarsal really results in impairment of function from diminished weight transmitted through this segment, one would expect that the first attempt at compensation would not be pronation of the fore part of the foot, as stated by Morton, but increased use of the flexor hallucis longus This compensatory mechanism has a high degree of efficiency, and often is used to advantage in such conditions as hypermobile flat-foot with short tendo achillis

The remaining factors in the syndrome which are said to influence function are hypermobility of the first metatarsal segment, posterior displacement of the sesamoids, and thickening of the shaft of the second metatarsal

Hypermobility of the First Metatarsal Segment

In spite of painstaking effort, we were unable to devise any method whereby the existence of this feature could be detected and recorded By clinical examination we could not discover any case in which we thought the first metatarsal segment was so much more mobile than the second as to constitute a possible cause of disturbed weight-bearing The roentgenographic evidence advanced by Morton (widening of the interspace between the first and second cuneiforms) is not pathognomic It results merely from the chance that the central beam of the roentgenogram has passed directly through the joint space In our opinion, hypermobility of the first metatarsal segment does not exist as a separate entity

Posterior Displacement of the Sesamoids of the Hallux

There is considerable variation in the position of the sesamoids in relation to the anterior end of the first metatarsal The extreme range of variation is 16 millimeters (7 5 to 23 5 millimeters), but the great bulk of the cases fall within the range of 12 5 to 16 5 millimeters

We have been unable to determine that there is any relationship between posterior displacement of the sesamoids and excess weight borne by the heads of the second or the second and third metatarsals This feature does not seem to be a cause of disturbed weight distribution in the fore part of the foot, any more than is shortness of the first metatarsal

Thickening of the Shaft of the Second Metatarsal

We were unable to find any direct association between thickening of the shaft of the second metatarsal and shortness of the first metatarsal On the other hand, when the presence of callus indicated that excess weight was borne by the second and third metatarsals, in 44 7 per cent there was thickening of the shaft of the second metatarsal However, many cases with thickening of the second metatarsal presented no evidence of excess weight borne by it It may be assumed with reasonable accuracy that, when the second metatarsal bears increased weight for any reason and has done so since childhood, it will respond with increase in size, but there is no evidence that shortness of the first metatarsal is the cause of such excess weight-bearing

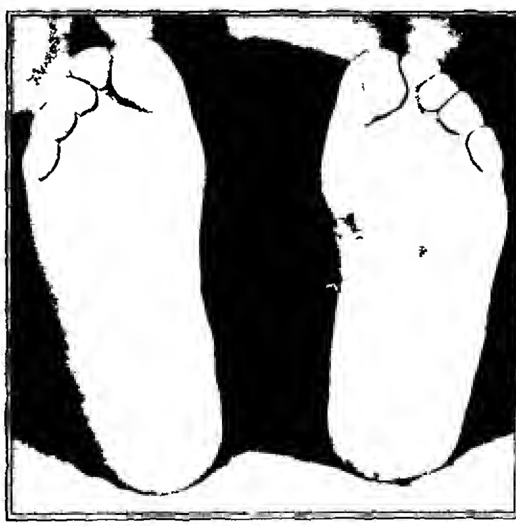

Fig 3-C
Photograph of same feet

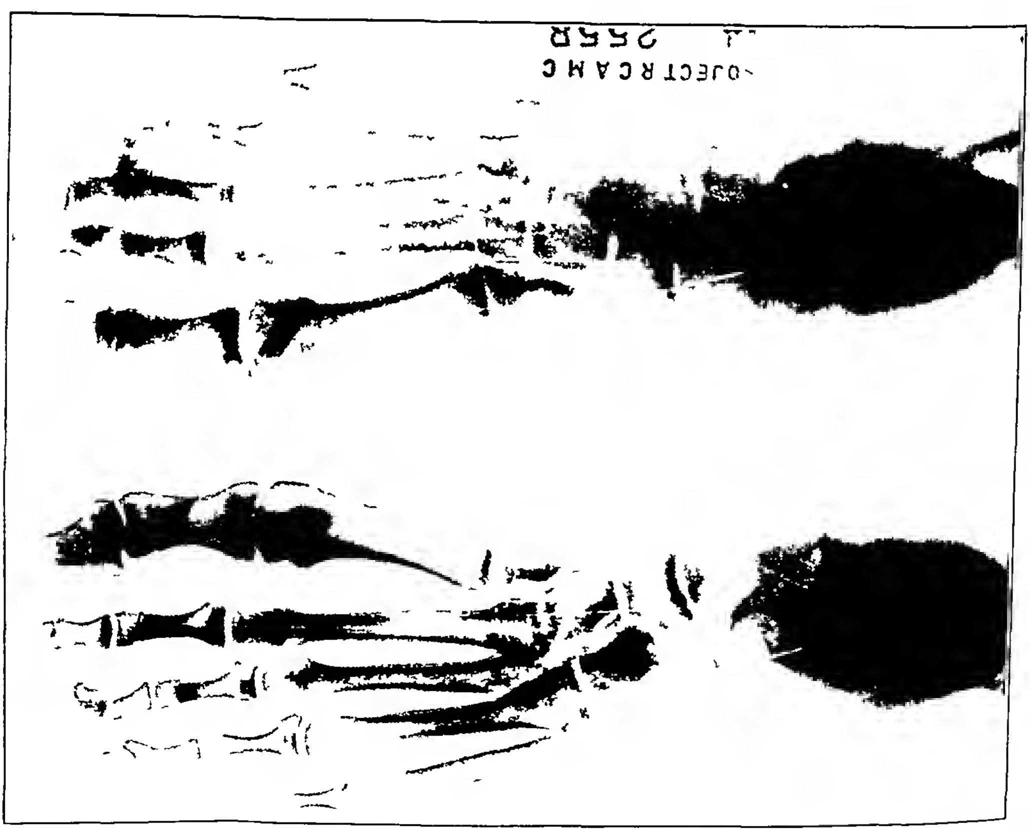

FIG 4-A

Another example of very short first metatarsal (—8 millimeters) without accompanying disability

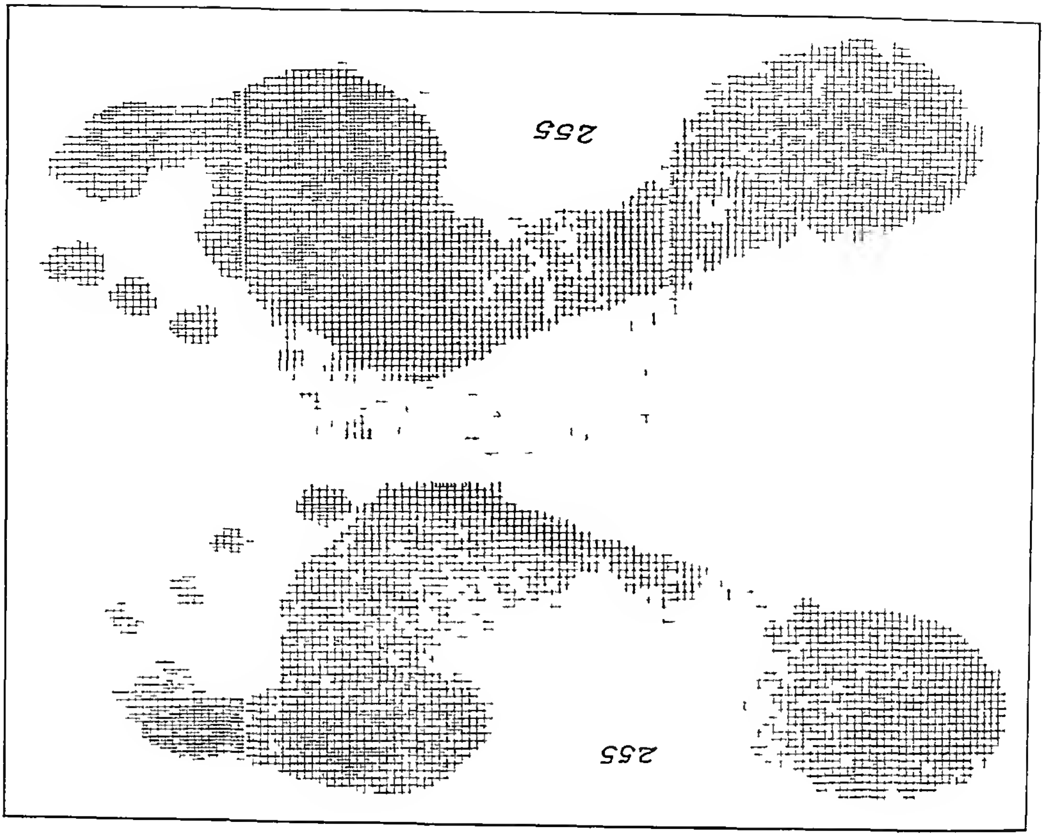

FIG 4-B

Footprints of the same patient show no localized pressure under metatarsal heads

FIG 5-A

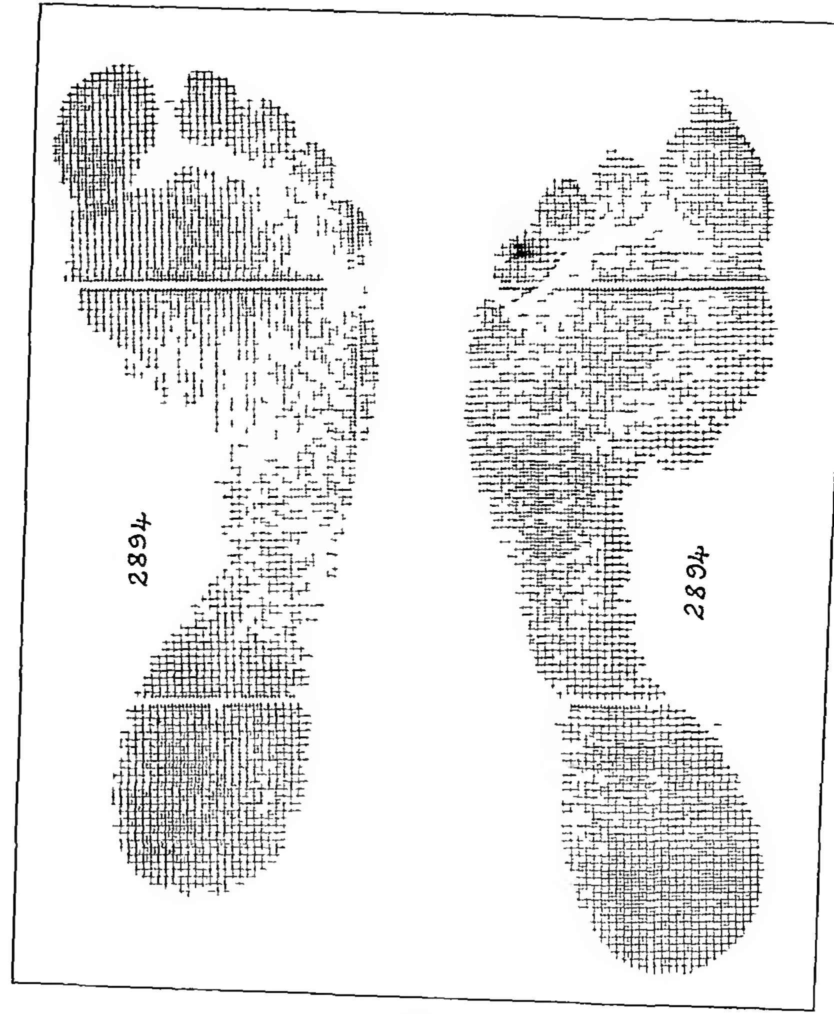

FIG 5-B

Fig 5-A A case with long first metatarsal (+5 millimeters) without evidence of local excess pressure under any metatarsal head and without symptoms Although the first metatarsal head is longer than the second, the shaft of the second is thickened

Fig 5-B Footprints of the same patient show no localized pressure under any metatarsal head

Fig 6-A

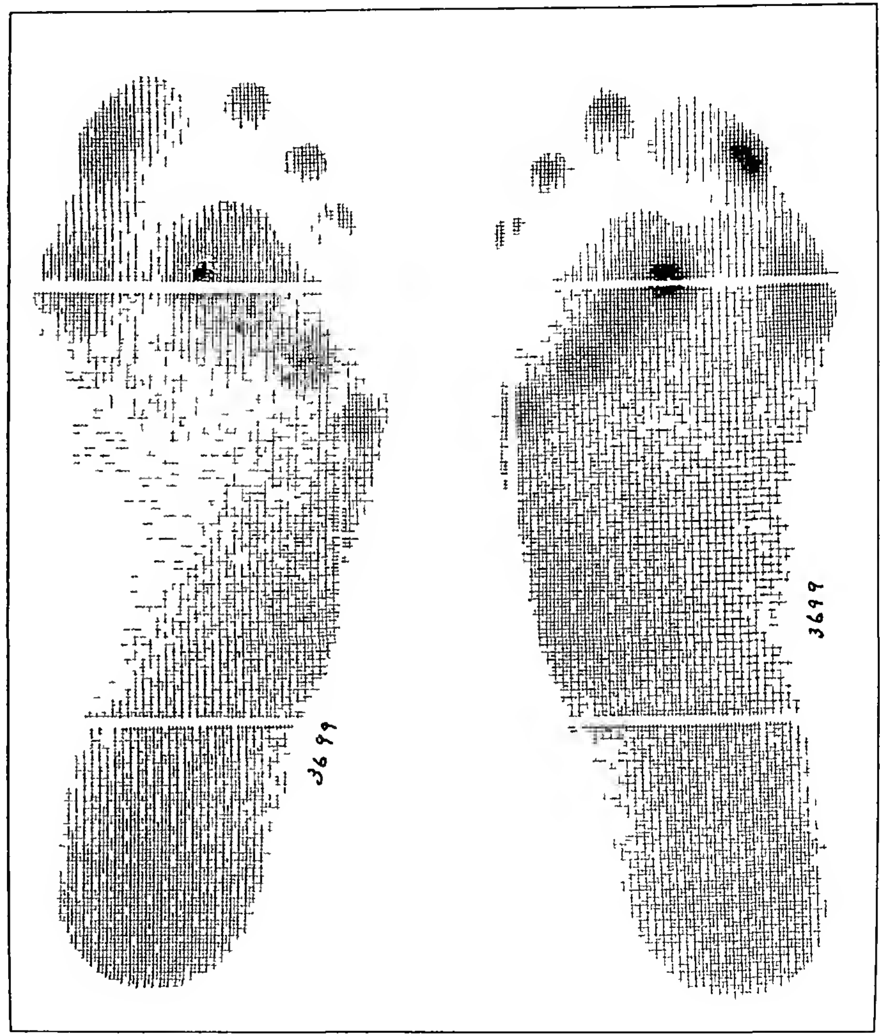

Fig 6-B

Fig 6-A Splay foot metatarsal heads are widely separated In spite of appearance, measurement from posterior end of calcaneus to heads of metatarsals shows left first metatarsal to be 1 millimeter longer than second and right first metatarsal to be 1 millimeter shorter than second

Fig 6-B Footprints of same patient show local excess weight-bearing beneath heads of all metatarsals

The Problem of Callus

The exact nature of callus and its causation is not easy to determine In general terms, it is produced by pressure upon a limited area of skin Under the influence of this local pressure, characteristic changes develop in the cornified layers of the skin,—cementing together into a homogenous mass the epithelium which normally would desquamate As the cornified layer becomes thicker, it intensifies the local pressure and perpetuates the lesion

The manner in which local excess of pressure is developed is obscure In all probability several factors are involved, singly or together, of which the following play a part

1 If the *toes* are clawed, even to a small degree, the long toe flexors no longer press the toes firmly against the ground so as to bear their share of the body weight and the thrust of the stride This transfers more weight to the ball of the foot where, sooner or later, calluses develop under the heads of the metatarsals

2 If the *foot* is clawed, the metatarsals are directed more steeply downward and weight is concentrated upon the metatarsal heads, because less is borne by the mid-portion of the foot

3 The quality and the thickness of the pad of subcutaneous tissue may be altered so that weight is less widely distributed upon the skin surface

4 When there is muscle weakness or paralysis, weight may be concentrated upon limited areas of the sole of the foot, from which it cannot be shifted because of deficient muscle power

5 While change in position of the metatarsal heads in relation to each other, or "falling of the anterior arch", is a recognizable clinical entity, the mechanism of its production is not clear Probably more than one factor is involved (Figs 6-A and 6-B)

6 Certain skins perhaps form callus more readily than others

7 There is a time factor concerned with the development of calluses In childhood they are rarely seen, in young adult life they are rare, past middle life they are common This might mean that it takes a long period of local excess pressure to cause callus, or that the factors which lead to the development of localized pressure appear only in the later decades of life

DISCUSSION

The findings of the Canadian Army Foot Survey lead to the conclusion that a short first metatarsal seldom, if ever, is the cause of foot disability Soldiers undergo the stren-

TABLE II

NUMBER OF CASES WITH EVIDENCE OF DISTURBED WEIGHT-BEARING *

	Local Excess Weight-Bearing, as Evidenced by Footprint and by Callus beneath Metatarsals			No Local Excess Weight-Bearing as Evidenced by Normal Footprint and No Callus	Total Number
	Second or Second and Third Metatarsals	Third or Third and Fourth Metatarsals	Total		
First metatarsal short by measurement	6½	7½	14 (1.1%)	1,268	1,282
First metatarsal not short by measurement	13½	7½	21 (0.9%)	2,316	2,337
Totals	20	15		3,584	3,619

* Because of frequent asymmetry, each foot is considered as one-half a case

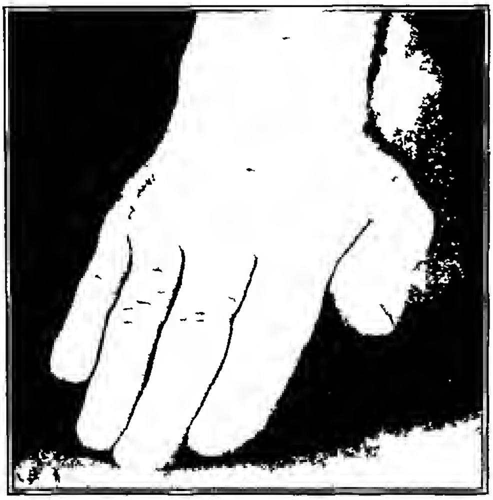

FIG 7-A

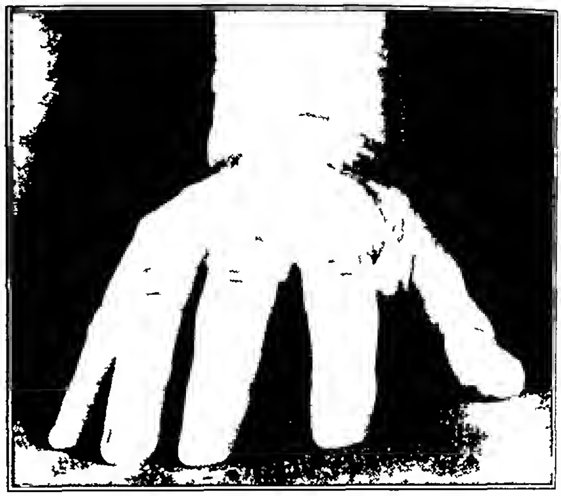

FIG 7-B

Fig 7-A To illustrate by analogy the mechanism whereby the metatarsal heads reach the ground and bear weight, despite differences in length If the metatarsals were on the same transverse plane, the longest metatarsal would reach the ground first and bear the most weight

Fig 7-B The metatarsals are not all on the same transverse plane, but are arched so that the central metatarsals are on a higher plane than the first and fifth In consequence, equal weight can be borne by all metatarsal heads, even though the first is shorter than the second, provided the metatarsal arch is maintained

uous activity of military training with no disability from short metatarsals, and react in no way differently from those who have long first metatarsals

On the other hand, callus under the heads of the central metatarsals occurs in 0 97 per cent of young men, and is the cause of appreciable disability It is not specifically related to short first metatarsals, in the vast majority of which this evidence of local excess of pressure is not displayed Also, it occurs almost as frequently in feet in which the first metatarsal is longer than the second It probably is due to sharp concentration of pressure under a metatarsal head prominent for reasons entirely different from shortness of the first metatarsal

Measurable shortness of the first metatarsal relative to the second does not necessarily mean that it cannot as readily reach the ground and that less weight will be transmitted through this bone The obliquity of the metatarsals in relation to the ground means that all can share equally in weight-bearing, provided the longer metatarsals are on a higher plane than the shorter This normally will be the case if the metatarsal arch exists It is then possible for the second and third metatarsals to extend farther forward than the first before reaching the ground, because they are at the apex of the metatarsal arch (Figs 7-A and 7-B)

In any case, the efficient use of the foot to support the weight of the body and to propel it in walking and running is not entirely dependent upon perfection of structure, even though this is of importance In feet which are not perfect in their structure, compensatory mechanisms of considerable efficiency develop, which tend to offset the ill effect that might arise as the result of deviation from standard structure In the case of the first metatarsal segment, the flexor hallucis longus, as has already been indicated, can provide the necessary supplement to function After all, foot function is dynamic as well as static

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DISCUSSION

DR ROBERT BINGHAM, RIVERSIDE, CALIFORNIA Dr Beath and Dr Harris are to be congratulated for this excellent study, which is a distinct contribution to medical and orthopaedic knowledge in two respect

First, by roentgenograms they have demonstrated the incidence of the short first metatarsal. Second, this study demonstrates that a great number of persons with the anatomical variation known as short first metatarsal do not have clinical symptoms, due to the compensating potentialities of the human foot. Because this study was conducted on a large group of young, physically fit men, the application of the conclusions to the human population as a whole must be considered.

Of the 3,619 persons whom they examined, slightly more than a third were studied for foot function during military training and, of these, only eighty-six are recorded as presenting symptoms. Among the thirty-five men with calluses under the middle metatarsals, only fourteen also had a short first metatarsal segment. Of this entire series of young men, therefore, only fourteen had painful feet as a result of Morton's syndrome or congenital insufficiency of the first metatarsal segment. This is too small a group upon which to base general conclusions.

In one American Army camp, we studied a group of 10,000 soldiers, in 332 of whom painful feet developed during their six months of military training. Of these, thirty-four, or slightly more than 10 per cent., had symptoms which we believed were due principally to the syndrome which Morton has described. By compensating for this functional insufficiency of the first metatarsal segment with the specific treatment recommended by Dr. Morton, we were able to return 76 per cent. of these patients to duty. In orthopaedic surgery, we have many examples of anatomical variations which frequently cause no disability, but which may, with increasing years or physical strain, produce clinical symptoms. Pes planus, an unstable lumbosacral joint, and spondylolisthesis are some of these. Insufficiency of the first metatarsal segment is, therefore, an anatomical variation which is potentially disabling.

Dr. R. Plato Schwartz, Rochester, New York: Acknowledgment of indebtedness is due to Dr. Harris and Dr. Beath for this valuable contribution. It is an exceptional instance of clinical methods of investigation applied to a mass of available material to determine the validity of a concept which was recognized on the basis of the data presented to support it.

Because of the thorough investigation leading to the conclusions reached by the authors, there would seem to be little indication for the repetition of measurements to reaffirm the absence of correlation between disabilities of the fore part of the foot and the Morton syndrome as the cause.

These conclusions are further supported by measurements of oscillographic records of the function of feet, with and without the characteristics common to the Morton syndrome.

1. Pressures recorded over the second metatarsal head, in the presence of a short first metatarsal, are found to be essentially the same as when the Morton syndrome is absent.

2. A one-eighth-inch elevation of the first metatarsal head is functionally characterized by an increase of pressure of about 20 per cent., limited to the levels of the first metatarsal head and great toe. There is no significant change induced in the pressures over any of the other four recorded levels of the foot.

3. Pronation begins with the reception of body weight by the heel. Since the first metatarsal is not functionally significant during the first 65 per cent. of the stance phase of the step, it is difficult to logically attribute effective control or prevention of pronation to a localized pressure increase at that level.

Many factors have been mentioned by Dr. Beath and Dr. Harris in reference to the cause of callus,—namely, that it does not occur with any degree of significance until the latter decades of life. They stress the point that the conditions under which the foot works and the relative mobility of the toes bring about a condition which is easily recognized as a precursor of symptoms referable to the formation of callus. One of the earliest indications, whether it be in civilian practice or in military life, of the shortcomings of function prodromal to the ultimate development of callosities, is that passive plantar flexion is usually limited earlier in the second toe than in any of the rest. This does not mean that calluses will always develop, but it is one of the first indications of functional impairment of the fore part of the foot.

A study of the inside of a shoe which has been in the closet without a shoe tree will give evidence of a depression where the plantar surface of the foot has functioned. Such depressions provoke limitation of plantar flexion of the toes. The relative fixation of the toes in dorsiflexion, in successive pairs of shoes, provokes depression of the metatarsal heads. The resulting depression of metatarsal heads becomes a major factor favoring atrophy of the plantar fat pad, either alone or in addition to callosities.

Dr. R. I. Harris (closing): We are reporting the findings of our Survey because there has seldom been such an opportunity for the mass study of foot problems. As far as we know, no such survey has been made before. We are well aware of the limitations which Dr. Bingham pointed out. It is true that we report only the findings in certain age groups. Nevertheless it was a carefully planned and precisely executed study of a considerable number of young men, the findings from which seem important.

I should like to pay tribute to my colleague, Dr. Beath, who really did all the work in the Survey. This could not have been carried out without his tremendous energy, drive, and persistence during a period of nearly two years.

ACUTE TRAUMATIC POSTERIOR DISLOCATION OF AN INTERVERTEBRAL DISC WITH PARALYSIS

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As the speed of automobile travel has increased and accidents at high velocities have become more common, a corresponding rise has been noted in the frequency of injuries to the spine and spinal cord Much attention has always been given to fractures and fracture-dislocations of the spine, causing paralysis, because the diagnosis is quite obvious in the roentgenographic examination However, very little comment has been made about acute traumatic displacement of an intervertebral disc in the causation of paraplegia Perhaps this is due in part to the fact that the disc herniation is not apparent on the roentgenogram At any rate, physicians have not been paying sufficient attention to this entity in the differential diagnosis of spine injuries

Many papers have been written about compression of the spinal cord or the cauda equina by herniated discs, but in most of these cases the patients have had a history of gradual progression of symptoms for an interval of days or weeks between the initial trauma and the onset of paraplegia [3, 4, 9-15] A few isolated cases of acute traumatic herniation of an intervertebral disc have been reported In 1911, Middleton and Teacher presented the case of a man who had lifted a weight, heard a cracking in his back, and was unable to straighten up Twenty hours later complete paraplegia developed with a sensory level at Poupart's ligament bilaterally, and the patient died sixteen days later At autopsy a herniated disc was found between the twelfth thoracic and first lumbar vertebrae, which had compressed and softened the cord Middleton and Teacher cited a similar type of case with rapid onset of paraplegia, caused by herniation of a disc at the first to second lumbar interspace, which had been reported by Kocher as early as 1896 Middleton and Teacher stated at the conclusion of their article "The rupture of an intervertebral disc during muscular effort may prove to be a very rare injury, but it may prove to be the explanation of certain cases the nature of which has been regarded as quite obscure, or which have been ascribed to the rupture of a vessel in the cord during exertion"

In 1911, Goldthwait called attention to a case of sacro-iliac subluxation in which complete paraplegia developed a few hours after his manipulation After numerous careful studies, he concluded that the disc at the lumbosacral joint had been extruded He stated " the writer cannot help wondering if some of the cases of so-called transverse myelitis or cases of paraplegia without bone or neoplastic disease are not due to these features"

However, it was not until 1944 that Brooke reported another case of acute complete transverse myelitis, secondary to traumatic herniation of an ossified nucleus pulposus in the cervical region Later in the same year Cramer and McGowan described a patient in whom immediate complete transverse myelitis had developed, due to herniation of a cervical disc, and they pointed out the part played by the nucleus pulposus in "recoil" injuries of the spinal cord

The author believes that acute cases, whether due to recoil of the disc or to complete extrusion with compression of the cord or cauda equina, are more frequent than is realized Three such cases, observed in the past three years, are reported here In the first case, acute extrusion of the nucleus pulposus occurred within the thoracic region, with rapid development of paraplegia Each of the other two patients had acute herniation of a disc in the lumbar region, with compression of the cauda equina and immediate paralysis

CASE 1 J W , fifteen years old, was thrown from a car on March 30, 1947 She was dazed for ten minutes and then complained of pain in the thoracic and lumbar portions of the spine with paralysis of the right leg

When the patient arrived at a hospital, about two hours after injury, the resident physician stated that she had a flaccid paralysis of the right leg, although ankle and knee jerks could be elicited One hour later paralysis of the left leg likewise developed The following day a neurological examination disclosed complete areflexic paraplegia with a sensory level at the fourth thoracic dermatome There was no plantar response to stimulation bilaterally A diagnosis of "traumatic myelitis" was made and surgery was considered However, it was not until April 1 that the patient was sent to University Hospital, Ann Arbor

At the time of admission the patient exhibited an areflexic paraplegia which was complete, except for vibratory sensation at the fourth thoracic dermatome, this was still barely noticeable at the iliac crests, but not below that level Roentgenograms of the entire spine showed only slight haziness of the inferior border of the second thoracic vertebral body, which suggested that there might be a mild compression fracture without displacement Lumbar puncture demonstrated a complete blockage of spinal-fluid flow on jugular compression, and a specimen of fluid removed at this time exhibited a four-plus globulin reaction Three cubic centimeters of pantopaque were injected into the subarachnoid space, and, after careful manoeuvring of the patient on a special frame on a tilt table, a complete block at the second to third thoracic interspace was demonstrated by fluoroscopy A lead marker was applied over the second thoracic vertebra for identification purposes, a spot film was taken, and the patient was sent directly to the operating room

About forty-eight hours after injury, laminectomy of the second and third thoracic vertebrae was performed At this interspace the dura and cord bulged posteriorly and were unusually taut Exploration revealed the large, completely extruded nucleus pulposus shown in *Figure 1*, with evidence of compression fracture of the inferior border of the second thoracic vertebra without displacement To remove the posteriorly displaced disc without further damage to the cord, the disc had to be excised by both an extradural and a transdural approach The cord and nerve roots were completely decompressed, the blockage to spinal fluid was relieved, and the incision was closed in layers From operation until discharge, six weeks later, the patient showed merely a drop in her sensory level with no change in her motor status or sphincter control A follow-up report on September 22 stated that the sensory level had further regressed to the eleventh thoracic dermatome However, there had been no return of motor function, and she still had a bladder disturbance of neurogenic origin

Examination of the specimen revealed a large piece of disc on which both cartilaginous and bony plates from adjacent vertebrae were still partially intact Fracture of these vertebrae had occurred, permitting extrusion of the disc The remainder of the fibrocartilaginous fragments had been removed piecemeal

The fact that cartilaginous and bony plates were still adherent to both the inferior and superior surfaces of the disc bears out Edye's contention "The body, being the weaker component, gives way first under the stress of violence The intervertebral fibro-cartilages act as buffers, as well as being the chief bond of union between the vertebrae The vertebrae are so firmly united to one another that injury is more likely to produce fracture or dislocation than a simple tearing of ligaments" The splinting of the thoracic spine by the thoracic cage prevents mobility, and, therefore, rupture of the intervertebral disc rarely occurs It is probable, as happened in Case 1, that fractures through the cortex of adjacent vertebrae must occur to permit extrusion of the disc This is in contrast to the mobility in both cervical and lumbar regions, where ligaments can be more readily stretched and torn, with subsequent herniation or extrusion of the disc, without fracture of the vertebral bodies

CASE 2 On August 18, 1947, F L S , a graduate nurse, was found unconscious with her trunk flexed in a jackknife position, lying halfway out the door of a wrecked automobile After she had regained consciousness, about ten minutes later, it was discovered that she was paralyzed from the waist down She was treated symptomatically at a local hospital and then transferred to University Hospital on August 20 At the time of admission her sensory level was one segment lower than at the time of the accident She felt the urge to void, but was unable to do so and had to be catheterized There was hypo-aesthesia from the twelfth thoracic dermatome downward, complete areflexia, and motor loss in the thighs, legs, and feet There was a slight flicker of movement in the hip flexors Rectal tone was entirely lacking Roentgenograms were negative for fracture or dislocation, with the exception of linear fractures of the transverse processes of the third lumbar vertebra bilaterally Lumbar puncture with jugular compression was performed, and there was an abrupt rise of 150 millimeters in the spinal fluid, with a correspondingly rapid drop Nevertheless, because of the patient's sensory level, 3 cubic centimeters of pantopaque was instilled, and on myelography a complete block was found at the first to second lumbar interspace This persisted, although the patient was placed in an almost completely vertical head-down position A diagnosis was made of herniated nucleus pulposus at this interspace

About fifty hours after the injury, a laminectomy of the first and second lumbar vertebrae was performed, and a large piece of extruded disc (Fig 2) was found This portion of the disc was lying free in the

FIG 1

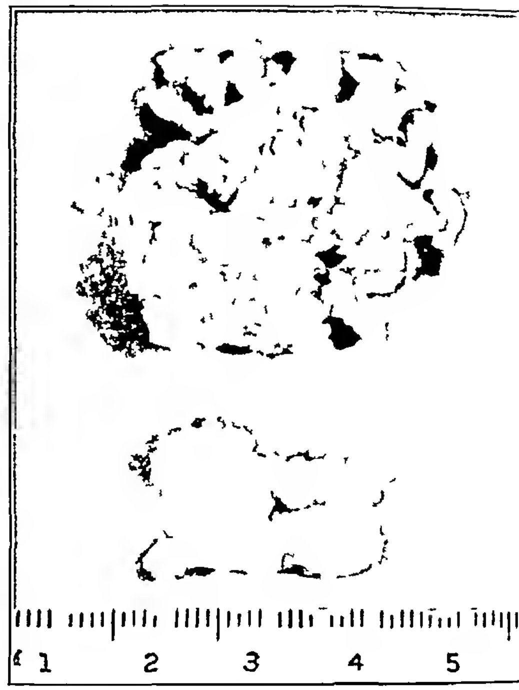

FIG 2

In each illustration, the portion of specimen immediately above the ruler is a single piece of disc, which was found lying free in the spinal canal The remainder of the specimen is the part of the disc which had been curetted away piecemeal

canal, just to the left of the mid-line, causing marked compression of the dura From the size of the hole in the ligament, it was apparent that some of the free disc might have slipped back into its original bed The interspace was thoroughly curetted down to bone and all loose disc tissue was removed The dura was opened and on the left side a few cauda equina roots showed a reddish-purple discoloration, but otherwise there was no abnormality Spinal fluid flowed freely and, since the cauda equina did not appear markedly swollen, the dura was closed tightly

Within sixty hours, the patient had a complete return of sensation, but there was no voluntary motor function and cystometric examination revealed a bladder disturbance of neurogenic origin Seventy two hours after operation the patient had good movement of her hamstrings and a very definite sense of fullness in her bladder Ten days after injury she was discharged to a hospital near her home At that time she had complete return of sensation and bladder control, but there was still complete areflexia of her lower extremities with just a slight flickering of her toes bilaterally

In a follow-up letter on January 12, 1948, the patient stated that there was full movement of her lower extremities in all directions with slight residual weakness in the hip flexors and dorsiflexors of her feet, but that these were improving daily Two small areas of hypo-aesthesia were present on the left thigh and leg, but these were disappearing gradually She wears a back support, goes up and down stairs, and is able to carry on light housekeeping duties

There is reason to believe that this patient might have recovered partial function without operation Her neurological findings suggested that her lesion was slightly higher than the point of complete blockage of the pantopaque, as seen at fluoroscopy However because of the latter finding, it was deemed advisable to operate Undoubtedly, the patient would have come to operation for severe pain at a later date, because of marked compression of the left nerve root by an extruded disc at the first to second lumbar interspace

This case seems important because the Queckenstedt (jugular compression) test was negative, and yet there was complete blockage of the pantopaque at the site of extrusion

CASE 3 On March 9, 1945, O B , a soldier, aged twenty-six years, became intoxicated at a social gathering in France Upon attempting to run upstairs, he suddenly experienced severe sharp pain in the lower portion of the back, fell down, and was unable to walk He noted numbness in his feet and buttocks, and he was unable to void There was no pain as a result of coughing or straining At a forward medical installation a diagnosis of hysteria was made, and the patient was evacuated as a neuropsychiatric casualty Seventy two hours later, on March 12, upon admission to the Thirty-sixth General Hospital at Dijon, France, he presented the following neurological picture

There was pain at the fourth to fifth lumbar interspace, and gentle percussion at this point greatly increased his discomfort. The patient could not stand, but in the recumbent position there was no radiation of pain into the legs on jugular compression. There was pain on straight-leg raising at 20 degrees bilaterally. Weakness was present in both right and left lower extremities, with complete paralysis of all movements of both feet. Hypo-aesthesia was present in the fourth lumbar, fifth lumbar, and first sacral dermatomes on the right. The patellar reflexes were hyperactive bilaterally, whereas both Achilles jerks were absent. A diagnosis of centrally herniated nucleus pulposus was made by Lieutenant Colonel J. E. Webster. Lumbar puncture was performed, and the spinal-fluid protein was found to be 96 milligrams per 100 cubic centimeters. Lipiodol was introduced into the spinal canal, and an invaginating defect, 1 centimeter in diameter, was noted at the fourth to fifth lumbar interspace on the left.

Early on the morning of March 13, about eighty-four hours after injury, the patient had a laminectomy (performed by Lieutenant Colonel J. E. Webster, assisted by the author) under general anaesthesia, a huge protruded disc, markedly compressing the left side of the dural sac at the fourth to fifth lumbar interspace, was found to be present. This was incised and the contents were removed piecemeal.

The patient had an average convalescence. At the time of evacuation to the United States on April 25, he had had only moderate improvement in power of his lower extremities, with the right showing further recovery than the left. No movement in any direction was evident in either foot. A loss of sensation in the sacral dermatomes remained. The right patellar and hamstring reflexes were normal. The left patellar and hamstring reflexes and both Achilles jerks were absent. Voluntary bladder control was present, with urgency and occasional incontinence. He was unable to stand.

In a follow-up letter from this patient on January 12, 1948, he stated that he was able to walk with the aid of a back brace and a lock type of brace to compensate for his foot-drop on the right. The left foot was completely normal in all movements. There was still hypo-aesthesia in the fourth lumbar, fifth lumbar, and first sacral dermatomes on the right, as well as in the saddle area. Occasionally there was hyperaesthesia in these areas and mild involuntary jerking spasms in the legs. Control of the vesical sphincter was good, but he had lack of sensation in his rectum and was always constipated.

In this case a faulty diagnosis of hysteria was originally made without a satisfactory neurological examination, a lumbar puncture with studies of the spinal-fluid dynamics, or a myelographic examination. The patient's greatest neurological deficit now is on the side opposite to the one where greatest compression of the cauda equina was visualized at operation.

DISCUSSION

Unfortunately there is still a marked tendency on the part of many surgeons to overlook completely, or ignore until too late, those signs and symptoms which are indications for surgery in injuries of the spine and spinal cord. All too frequently the general attitude is that a cord injury is an utterly hopeless problem, and it is useless to do anything about it. As a result, those individuals who might have had a chance of recovery actually do become "hopeless cases".

The early indications for surgery in spinal-cord injuries are usually given as:

1. A history of progression of neurological signs.
2. Compound fractures of the spine, particularly in those cases with spinal-fluid leaks.
3. Marked encroachment of bony fragments upon the spinal canal, as exhibited in the roentgenograms.
4. With a lumbar-puncture needle in place, evidence of complete blockage of the spinal fluid on jugular compression.

To these it is believed a fifth should be added:

5. Evidence of blockage of a column of pantopaque upon myelographic examination in those cases which, in spite of a negative Queckenstedt test, have a definite sensory level.

The first two indications listed require no discussion, but the last three should be commented upon. It should be emphasized that, at operation, 30 or 40 per cent. more damage to the vertebrae may be noted than can be visualized in the roentgenogram.

As shown in Case 2, if one relies merely upon a positive jugular-compression test as an indication that operation should be performed, extruded discs may be missed. It is obvious that this test will be negative as long as a subarachnoid space of the diameter of a No. 20 needle is still present. The validity of the test is good for that moment during which

the procedure is being performed It is known that oedema may gradually develop in the injured cord or cauda equina hours or even a few days after this initial test has been performed, and, unless the procedure is repeated several times, a true surgical lesion may be overlooked For this reason it is advocated that early pantopaque myelography be performed in these lesions where there is no block to jugular compression, and yet a good sensory level is present

A word of caution is offered to those doing myelography on these individuals In order to prevent further damage to the injured cord, the patient should be anchored securely to a board on the x-ray tilt table, with a firm supporting yolk at the shoulders and adjustable ankle supports This enables tilting of the patient into an almost vertical head-down position, without compression of the vertebral column or the spinal cord

It would seem unnecessary to emphasize these criteria, but only too rarely are they followed In all of the cases reported here, operation was performed much later than it should have been, and the degree of disability has, at least theoretically, been increased proportionately These cases should be regarded as surgical emergencies After early accurate diagnosis, operation should be performed immediately by a competent surgeon, for the elements of the central nervous system do not, in general, withstand prolonged compression without the occurrence of irreversible anatomical changes

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CONGENITAL POSTERIOR ANGULATION OF THE TIBIA

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Congenital anterior angulation or bowing of the tibia has attracted the interest of orthopaedic surgeons for many years, chiefly because of the severity of the deformity and the difficulties encountered in treatment. Although the deformity is rare, many writers have considered it as related to congenital pseudarthrosis. Experienced orthopaedic surgeons are aware of the likelihood of non-union following fracture or osteotomy to correct the angulation.

Congenital posterior bowing, on the other hand, has not been described adequately. While rare cases may have been observed, they have not been reported sufficiently to make this type of bowing generally known as a separate entity. Since one of the writers has treated three such cases, and has observed them sufficiently long to know the outcome, it seems important to describe them and to report the results of conservative treatment.

In the literature, practically all cases of bowing of the tibia are referred to as congenital angulation or congenital bowing, irrespective of the underlying pathological condition. Heretofore, two forms of congenital angulation have been well described and are recognized. It is the authors' purpose to add a third group, consisting essentially of posterior angulation with talipes calcaneus, and to differentiate this entity from other forms of congenital angulation.

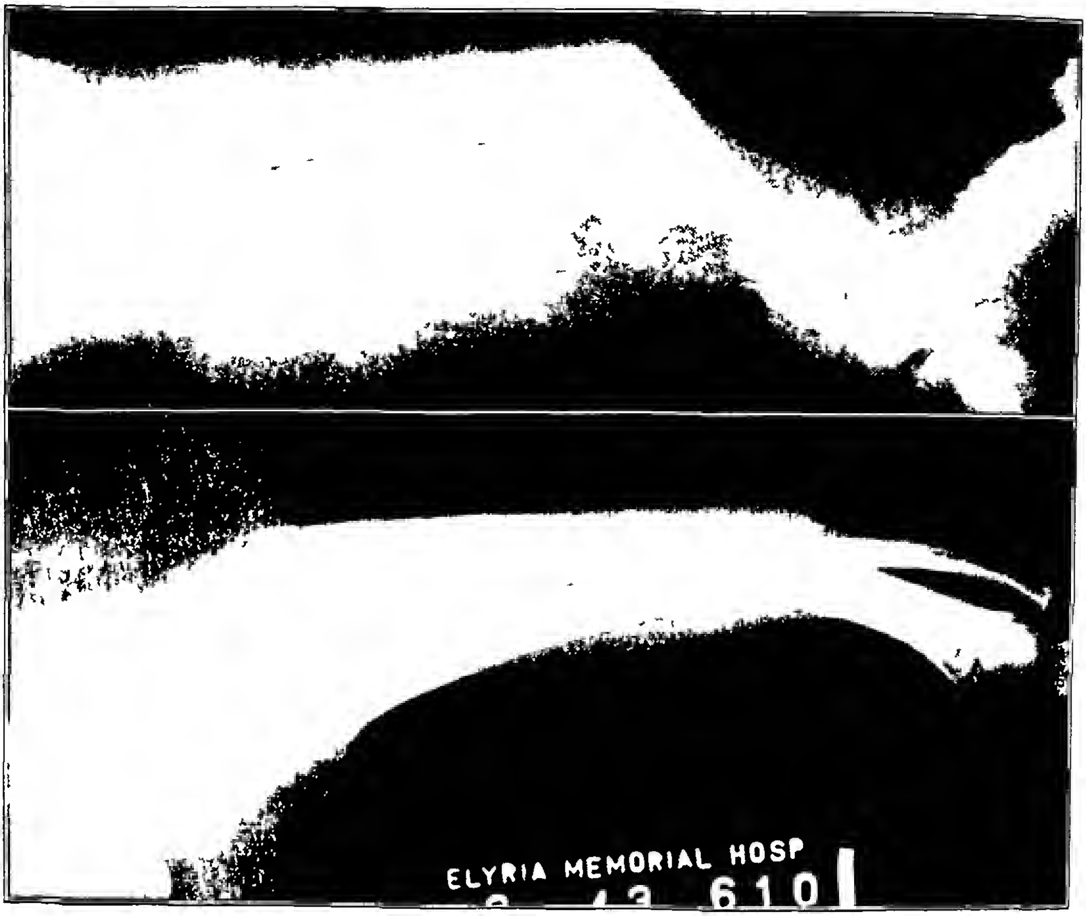
Group I

This is the form most commonly referred to. In all of these cases there is an anterior or a forward and lateral angulation of the tibia, and pseudarthrosis eventually develops. There may or may not be a dimple over the apex of the angulation. Although it is said that talipes equinus may be present before fracture has occurred, most patients are first seen when considerable bowing is already present or after fracture with shortening of the tibia, allowing the foot to assume a position of calcaneus. The bone is usually small and sclerotic, and the medullary canal is diminished. In rare cases, however, no pathological change is readily demonstrable in the roentgenogram. The deformity is a local one, not associated with abnormality of other bones.

It is most commonly accepted that a primary defect exists in the structure of the tibia. This has been attributed to a fibrocystic lesion at the apex of the angulation (Figs. 1-A and 1-B), an associated neurofibromatosis, or a congenital deficiency or absence in the nutrient artery. Perhaps the most widely held theory of etiology is that of a defect in the germ plasm, which is a lesser manifestation of the same factor that results in congenital absence of the tibia. Freund, however, believed that the sequence of deformity and pseudarthrosis is not caused by a primary defect in the tibia, but rather that a disproportion of growth between the bone and the calf muscles causes the angulation and ultimately results in fracture and pseudarthrosis (Figs. 2-A and 2-B). His concept was similar to that of Middleton's explanation of the deformity in the next group.

Group II

The second group of congenital angulations of the tibia are those characterized by anterior bowing, associated with shortening of the calf muscles. There is [illegible]ere [illegible]d markedly resistant talipes equinus. Spontaneous fracture with pseudarth



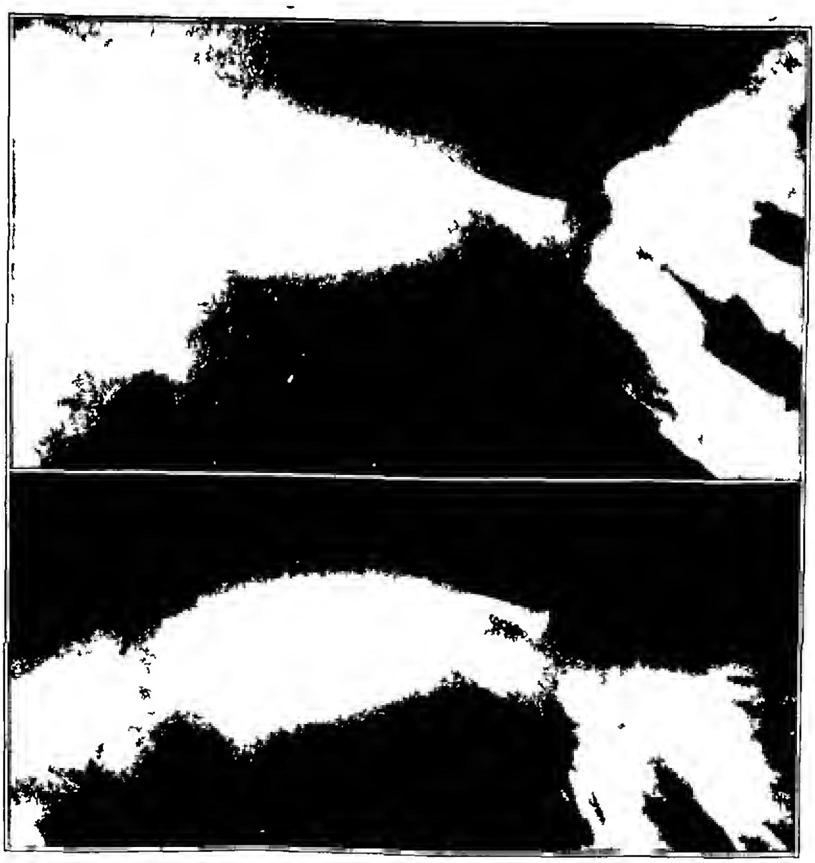


Fig 1-A

Fig 1-A Group I R K, two months of age Showing one type of congenital bowing with a fibrocystic lesion

Fig 1-B Same patient at three years of age Early curettage of the cyst and packing with bone chips did not prevent pseudarthrosis and severe anterior angular deformity

The deformity was subsequently corrected and union appeared solid, four years after a dual bone graft

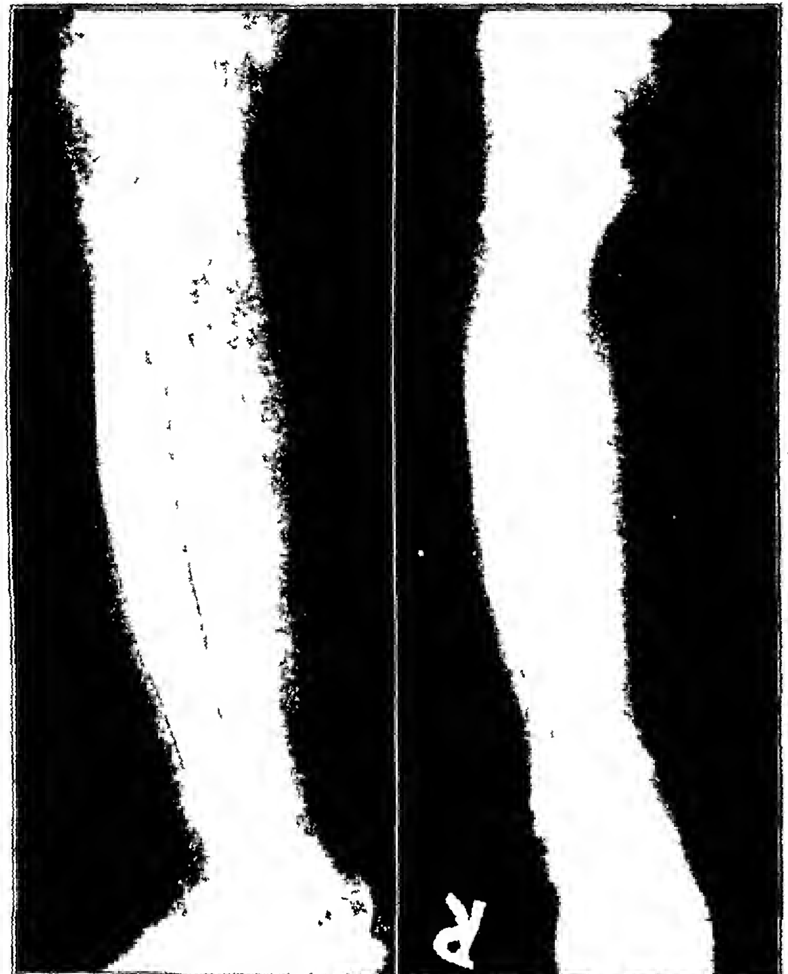


Fig 2-A

Fig 2-B

Fig 2-A Group I M B, at two years of age Illustrative of another type of congenital bowing There had been a recent fracture without known trauma There was sclerosis of the tibia at the site of the fracture

Fig 2-B At six years of age, typical pseudarthrosis was present after an unsuccessful bone-grafting operation There was marked anterior and lateral angulation Eventually the leg was amputated

FIG. 3

Group II. J. S., at the age of thirteen months. There was bilateral anterior angulation of the tibia, absence of the fibula, severe equinus deformity, and developmental abnormalities in the foot.

The child is now eleven years old. One foot has been amputated, the deformity of the other foot has been corrected. He is a normally active child, and there has been no fracture of either tibia.

rule, as in cases in Group I. While the predominating deformity is that of the tibia and foot, there is usually a coexistence of other anomalies of development, such as absence of some of the bones of the foot, syndactylism, absence of the fibula, and congenital dislocation of the hip (Fig. 3). There is usually marked shortening of the entire lower extremity, mostly below the knee. The roentgenograms reveal thickening of the tibia on

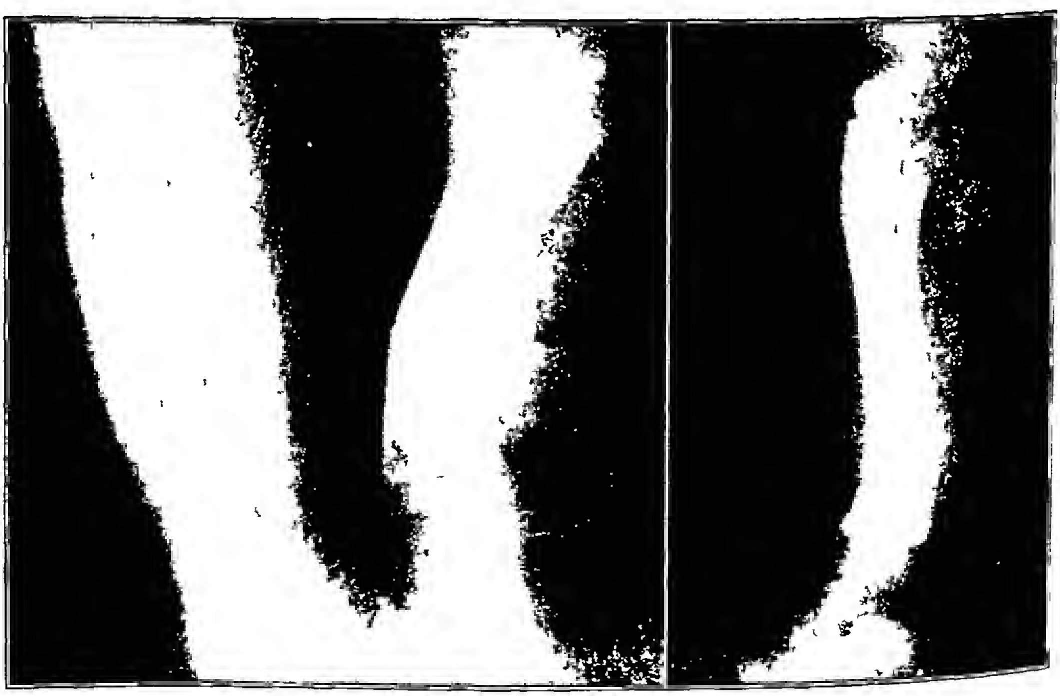


FIG. 4-A

Group III. M. A. S., at eight months of age, April 6, 1941. There was severe posterior and medial bowing of the left tibia and fibula at the junction of the middle and lower thirds. The upper and lower tibial epiphyses appeared normal as compared with those on the right, although the left leg was shorter. Ossification appeared normal, except for a rather marked increase of density on the concave sides of the curves.

the concave side of the curve, the sclerosis may involve the entire thickness of the bone. A dimple is present anteriorly at the apex of the angulation. A constant finding is a very tight tendo achillis with severe talipes equinus.

Freund, Kite, and Middleton have described this group of cases in detail. Freund considered the deformity as caused by a faulty anlage of the extremity. It was Middleton's opinion that the angulation is secondary to shortening of the calf muscles, due to failure "during intra-uterine life of the last stage of growth in length of the developing myocyte . . ." This would account for the fact that histologically the muscle cells were normal, but short. The muscles do not keep pace with the increase in length of the skeleton, leading to progressive functional shortening of the tendo achillis. Middleton did not believe, however, that congenital shortening of the muscle is the cause of the angulation in Group I. In many of the cases in this category the fibula is absent; this Middleton believed to be a concomitant anomaly, and not an etiological factor in tibial angulation. However, most of the patients with absence of the fibula also show tibial angulation, talipes equinus, a dimple over the apex of the curve, and shortening of the leg.

FIG. 4-B

May 27, 1948, at the age of seven years. Ossification and alignment of the tibia and fibula were essentially normal following conservative treatment. The leg had been without protection for four years.

Group III

This is the group of congenital angulations which the authors are submitting as a clinical entity, distinct from those in Group I and Group II. The cases are characterized by:

1. Posterior angulation or backward and medial bowing at the junction of the middle and lower thirds of the diaphysis of the tibia. The fibula is similarly bowed.
2. Severe talipes calcaneus.
3. Tightness of the anterior muscles of the leg and weakness of the triceps surae.
4. Presence of a dimple over the apex of the angulation.
5. Shortness of the lower extremity confined chiefly, if not entirely, to the leg, and underdevelopment of the muscles of the leg.
6. No detectable abnormality of the structure of the bone, other than a thickening of the cortex on the concave side of the curve.
7. No appreciable impairment of the upper or lower tibial epiphysis.
8. No unusual tendency to fracture.
9. Good prognosis with conservative treatment.

A review of the literature has disclosed only two cases that would fall into this category. In one typical case, reported by Freund in 1936, considerable improvement followed six months of treatment. A second case of posterior angulation of the tibia was

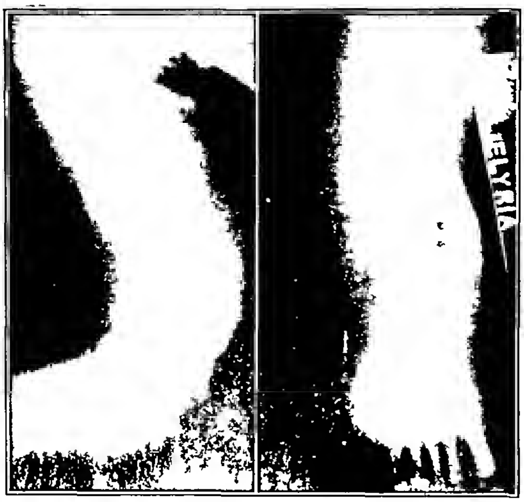


FIG. 5-A

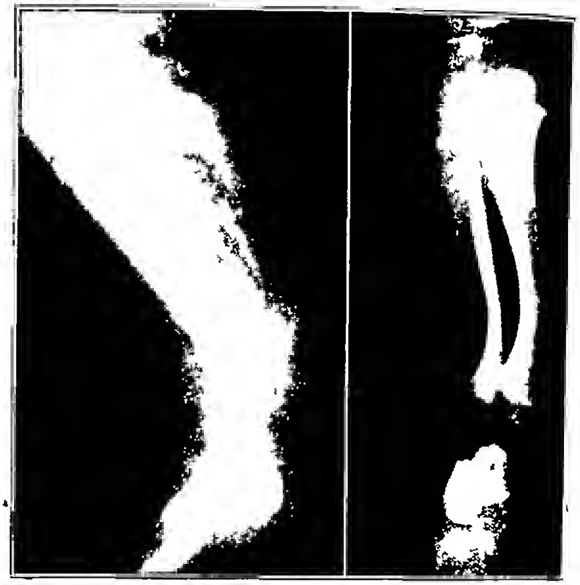


FIG. 5-B

Fig. 5-A: Group III. A. L. W., at six weeks of age, September 18, 1942. There was severe posterior and medial angulation of the tibia and fibula at the junction of the middle and lower thirds. Ossification was essentially normal, except for increased density on the side of the concavity.

Fig. 5-B: April 5, 1943, at eight months of age. There was appreciable improvement in the angulation. Both epiphyses appeared normal.

reported in 1943, by Diaz Bordeu. This patient, however, showed no muscle atrophy, shortening of the extremity, or calcaneus deformity. Voshell described the case of a four-month-old infant, which fits accurately into this group. The child is still a baby. The authors are reporting three cases, followed eight years, six years, and three years respectively.

The outstanding clinical feature of these cases is a good prognosis as a result of conservative treatment, in spite of the alarming early deformity. This at once contrasts congenital posterior bowing with the congenital anterior bowings.

The etiological factor would not appear to be a primary germ defect in the bone, since the tibia does become straight and is approaching normal in all respects in the last roentgenogram of the cases reported here. There is no fibrocystic lesion, evidence of neurofibromatosis, or sclerosis. In fact, the early roentgenographic appearance of the bone structure is normal, except for the increased thickness of the cortex on the concave side of the curve. This is probably a manifestation of Wolff's law, with thickening or condensation of the trabeculations along the trajectory of forces to meet the stress on the curved bone. A primary congenital shortening of the anterior muscles could explain the deformity, but this is not satisfying, because the muscles are not resistant to stretching, and they continue to grow in length. T

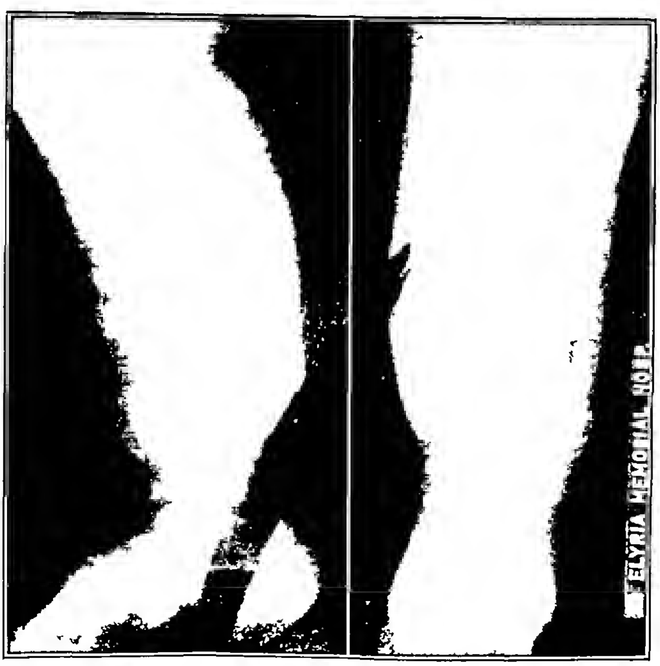


FIG. 5-C

September 1, 1944, at two years of age. Showing continued improvement under conservative treatment.

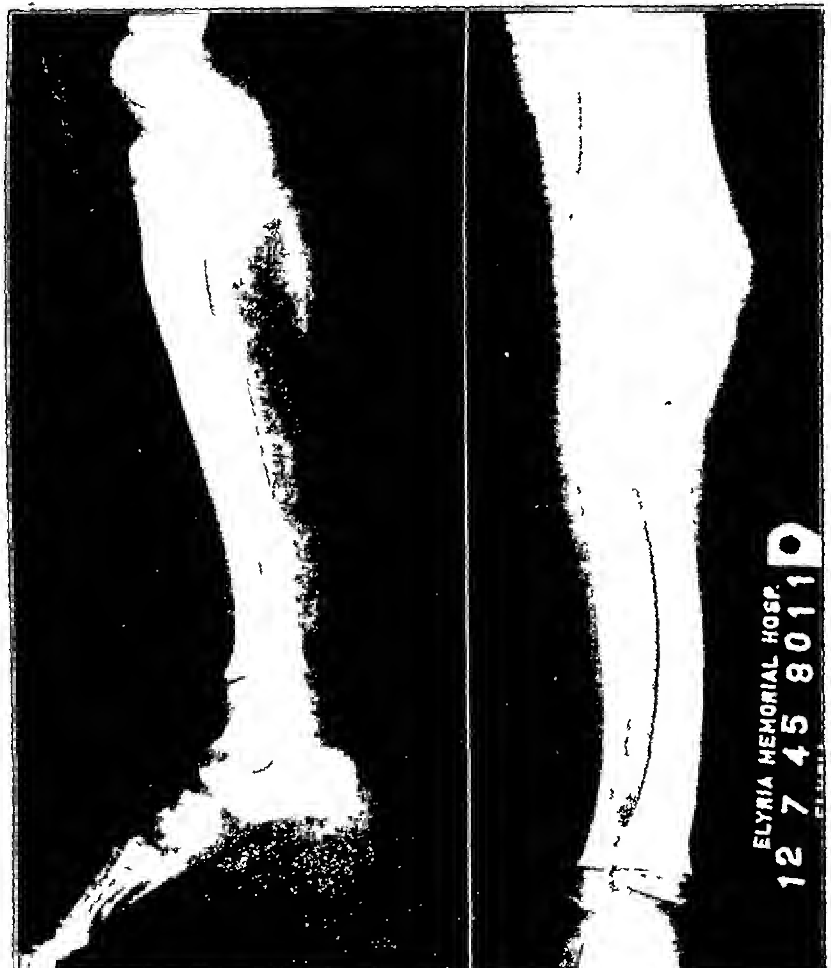


Fig 5-D

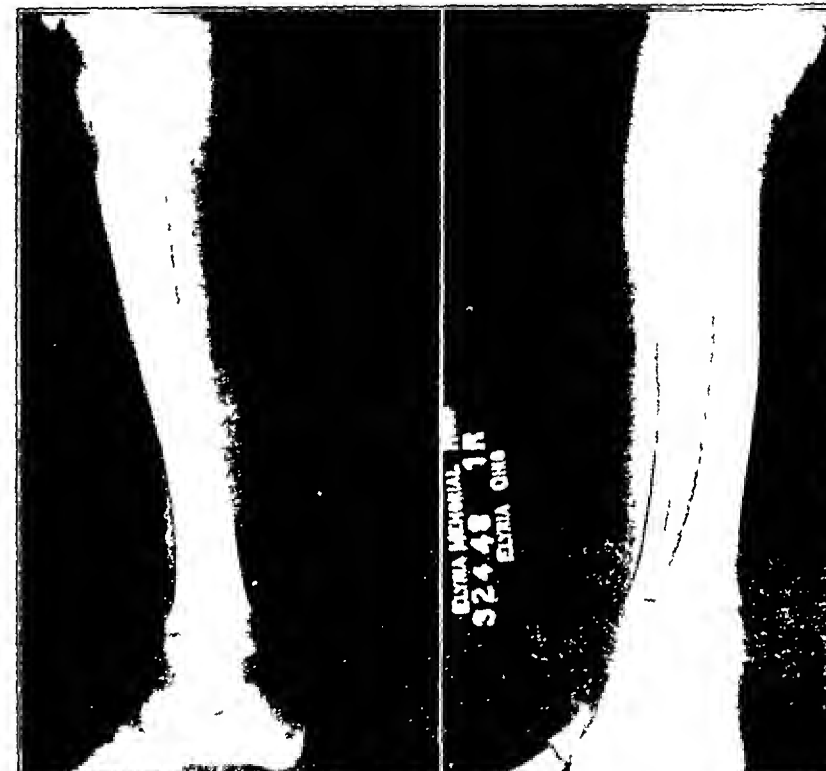


Fig 5-E

Fig 5-D December 7, 1945 Patient is three years of age

Fig 5-E March 24, 1948, at five and one-half years of age Bowing had almost completely disappeared and the bony structure was approaching normal Both epiphyses appeared normal The leg had been without protection for eighteen months

response to treatment would indicate an adaptive shortening due to position, rather than the extremely resistant shortening caused by a congenital arrest in development. On the other hand, the hypothesis of a primary shortening of the anterior muscles is attractive, because this would cause only a posterior or a posterior and medial bowing. Posterior and lateral bowing has not been encountered. It is obvious that posterolateral bowing could not be caused by a shortening of muscles on the opposite side of the leg, since there are no muscles on the anteromedial side. It is unlikely that an extrinsic force, such as abnormal intra-uterine pressure, caused these deformities, because all cases are essentially the same. Perhaps the embryologist may find the answer.

The treatment of congenital posterior angulation of the tibia is conservative

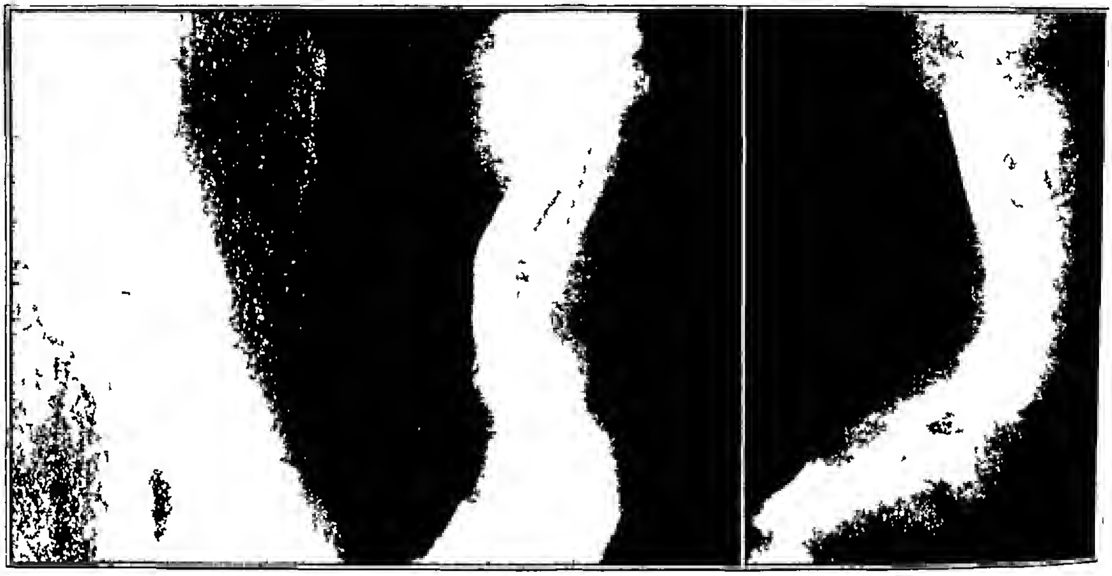


FIG. 6-A

Group III. R. R., August 3, 1945. At three weeks of age, there was severe posterior and medial angulation of the tibia and fibula with shortening of the leg, and increased density on the concave side of the curve, as in the cases of M. A. S. and A. L. W.

FIG. 6-B

April 5, 1946, at nine months of age. The tibial epiphyses on the left were comparable to those on the right. Shortening, however, was apparent. Ossification appeared normal, except for the increased density on the side of the concavity.

Osteotomy should never be performed, because of the likelihood of causing pseudarthrosis Even osteotomy with primary bone-grafting may result in failure of union The three cases of posterior angulation to be presented were all treated conservatively, with good results Therapy consisted of massage and stretching of the soft tissues which hold the foot in calcaneus, and fitting the patient with a toe-to-groin brace with a leather cuff capable of being tightened posteriorly at the site of the angulation A stop-joint was used at the ankle to prevent calcaneus The brace was applied as early as practical—at about five months of age, before the children began weight-bearing—and was continued until the angulation had been corrected by growth, and the calcaneus deformity had been eliminated by the appearance of strength in the triceps surae

Fig 6-C

July 16, 1948, at three years of age Marked improvement was evident

Growing bone is pliant, it yields slowly to pressure or to a bending force The brace, consisting of a doubled-back leather cuff, adjustable in tautness by means of straps and buckles between the rigid lateral uprights, exerts a continual pressure, directed toward straightening the tibia A stop-joint at the ankle to prevent calcaneus, together with manual stretching of the soft-tissue structures anteriorly, diminishes the resistant bowstring effect of the short anterior muscles

The patient, M A S , was first seen on September 17, 1940, at six weeks of age Examination revealed severe posterior and medial angulation of the left leg, immediately above the ankle joint, which had been present since birth There was a dimple posteriorly, over the apex of the curve The tendo achillis was lax and the dorsiflexors of the foot were contracted, causing a severe calcaneus deformity There were no *café au lait* spots No treatment had been given Roentgenograms showed severe posterior and medial angulation of the tibia and fibula at the junction of the middle and lower thirds (Fig 4-A) The bony cortex of the tibia and fibula was thickened on the side of the concavity Massage and stretching of the shortened soft-tissue structures were instituted to correct the calcaneus As soon as the child began weight-bearing, at nine months of age, the brace previously described was applied Although the epiphyses appeared normal by roentgenogram, the left lower extremity was approximately one inch shorter than the right, the shortening being all below the knee By April 29, 1944, the condition had improved markedly, so that there was practically no limp and no gross angulation There was good power in the triceps surae, and a normal range of motion in the ankle joint One inch of shortening remained The brace was then discontinued

The child is now eight years old, and walks with only a slight limp, due to one-half inch of shortening No gross deformity is detectable She has excellent muscle strength in the triceps surae, and a normal range of motion in the ankle joint Roentgenograms show no posterior angulation and very slight lateral angulation of the tibia and fibula (Fig 4-B) The bone architecture and the epiphyses appear normal

The patient, A L W , had been born with an angulation of the right leg, for which a plaster-of-Paris cast had been applied by a local physician, shortly after birth When the patient was first seen on September 4, 1942, at four weeks of age, there was a severe posterior and medial angulation of the tibia and fibula at the junction of the lower and middle thirds A dimple appeared in the skin over the apex of the angulation posteriorly The foot was in severe calcaneus The tendo achillis was lax, and the dorsiflexors of the foot were contracted There were no *café au lait* spots Roentgenograms, obtained on September 18, confirmed the angulation (Fig 5-A) There was no definite abnormality of the bone structure, although the bone density

on the concavity of the curve was increased The plaster immobilization started by the family physician was discontinued, and the patient was treated conservatively and kept under observation

At five months of age, a toe-to-groin brace was fitted to the right lower extremity, with a leather support posteriorly at the site of the angulation The child began walking at fourteen months of age Gradually the deformity of the leg and the calcaneus deformity decreased (Figs 5-B, 5-C, and 5-D) By November 1, 1946, there was only moderate calcaneus, good power in the triceps surae, and only slight angulation of the tibia The brace was discontinued at that time The shortening of the extremity was reduced to one inch It should be noted that the lower tibial epiphysis did not appear on the right until April 1943

Since November 1946, the patient has been quite well She is now six years old, and walks with only a slight limp due chiefly to weakness of the Achilles group of muscles There are one and one-fourth inches of shortening of the extremity, but no gross angulation The roentgenograms of the right tibia and fibula show mild medial bowing, and practically no posterior bowing (Fig 5-E) The bone architecture and the epiphyses appear normal

The patient, R R, was first seen on August 3, 1945, at three weeks of age The baby had been born with severe bowing of the left leg, just above the ankle He had had no treatment Examination showed severe posterior angulation (Fig 6-A), a dimple in the skin over the apex of the angulation posteriorly, and a severe calcaneus deformity The tendo achillis was lax, and the dorsiflexors were tight The left tibia and fibula were short in comparison with those of the right leg There were no *café au lait* spots No definite defect was noted in the bone architecture, although there was increased density of the tibia on the side of the concavity The only treatment given initially was massage and stretching of the tight dorsal structures At the age of nine months, when the child began to bear weight (Fig 6-B), he was fitted with the brace and a reverse stop-lock He learned to walk quite well with the brace, and he is still wearing this type, at the age of three years There has been steady, gradual improvement in the angulation, and also in the calcaneus deformity There is one inch of shortening of the left lower extremity, all below the knee Good power is present in the triceps surae, and a normal range of motion in the ankle joint Roentgenograms show only moderate angulation (Fig 6-C) The epiphyses appear normal

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CLOSED DRAINAGE OF THE KNEE JOINT FOLLOWING ARTHROTOMY

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Postoperative effusion of the knee joint is a frequent sequela of arthrotomy It is distressing to the patient and of concern to the surgeon, for it is painful and interferes with physiological healing Arthrotomy, of necessity, adds trauma to synovial structures which are often acutely or chronically irritated The extensive areas of synovial membrane

respond by effusion into the joint space, with resultant swelling and increase of intra-articular pressure The synovial membrane and capsule become tense and congested The presence of effusion indicates the direction of the flow of lymph from the joint synovial membrane and capsule into the joint cavity The egress of joint fluid into the lymphatics and capillaries is temporarily halted Repeated aspiration as a means of decompression of the distended joint is often resorted to

Many surgeons have found that non-suture or very loose suturing of the synovial membrane at the site of incision permits drainage of the effusion into the extracapsular or subcutaneous tissues, thereby preventing joint tension This has the disadvantage of producing a "pool" of synovial fluid along the line of suture, thus interfering with early, firm healing

A simpler means of permitting continuous drainage of the knee-joint cavity is presented here A drainage tract is established from the apex of the suprapatellar pouch to the deep muscle planes of the thigh by penetrating the synovial membrane and capsular folds with a blunt forceps, the forceps is introduced closed, and then opened before withdrawal The double curve of a medium-sized uterine packing forceps has been found to be ideal for this purpose It can be introduced through any type of incision, and is long enough to reach well beyond the joint cavity The drainage tract in this position permits escape of the joint fluid into an extensive intermuscular plane which is rich in lymphatics It also prevents the pooling of joint fluid along suture lines Early joint movement, active and passive, produces a "milking" effect and prevents sealing-off of the drainage tract

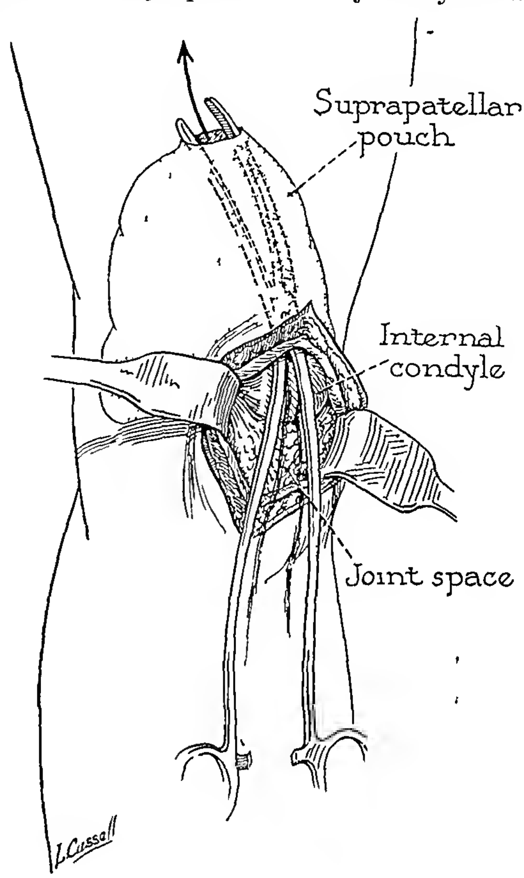

Fig 1

Method of puncture in the suprapatellar pouch by introduction of packing forceps through incision

Voluntary use of the extensor muscles of the knee, which is so important, is facilitated, reducing quadriceps atrophy to a minimum

The observations of Bauer, Short, and Bennett[1] show conclusively that the larger protein molecules, especially albumin, are absorbed through the lymphatic system rather than by capillaries This observation explains in great part the favorable course which usually follows muscle-plane drainage of postoperative effusion of the knee joint Similar synovial drainage of other joints is occasionally indicated

The use of this technique of drainage has almost eliminated postoperative effusion following arthrotomy of the knee joint, and postoperative pain and disability have been materially reduced

1 Bauer, Walter, Short, C L , and Bennett, G A The Manner of Removal of Proteins from Normal Joints J Exper Med , **57** 419–433, 1933

EVOLUTION OF METAPHYSEAL FIBROUS DEFECTS

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Localized defects in the metaphyses of long bones have been described as "cyst-like areas"[4], "non-osteogenic fibroma"[2], "metaphyseal fibrous defects"[1], and "monostotic fibrous dysplasia"[3]

The authors had the opportunity of following by roentgenograms, for a period of thirteen years, the evolution of such metaphyseal defects This case is unusual in that, during the period of observation, three such defects appeared and regressed in the same area of the upper humeral metaphysis

R B , a two-year-old boy was admitted to the Department of Orthopaedic Surgery of the State University of Iowa Hospitals on November 22, 1934, because of a curvature of the spine, present since birth. Physical examination and roentgenograms revealed a left convex thoracic scoliosis, due to congenital wedging of the third to the sixth thoracic vertebrae, and absence of the fifth rib on the left Roentgenograms of the spine at the time of admission included the right humerus, which appeared normal (Fig 1-A) Roentgenograms were taken at frequent intervals to follow the course of the scoliosis, and many of them included a view of the right humerus

FIG 1-A FIG 1-B FIG 1-C

Fig 1-A In roentgenogram taken at two years of age, right humerus appears to be normal
Fig 1-B At four years of age, a small metaphyseal defect may be seen
Fig 1-C At five years of age, because of growth of the bone, the metaphyseal defect has traveled away from the epiphysis It is outlined by sclerotic bone
Fig 1-D At five and one-half years of age, the first metaphyseal defect is still apparent, farther down the shaft A second metaphyseal defect is seen, arising in the same location as the first
Fig 1-E At six years of age, the first metaphyseal defect, which is in the humeral shaft, is becoming smaller, the second one, still in the metaphysis, has enlarged
Fig 1-F At six and one-half years of age, the first metaphyseal defect is very small and is located close to the center of the humeral shaft The second defect has enlarged and its borders have become sclerotic

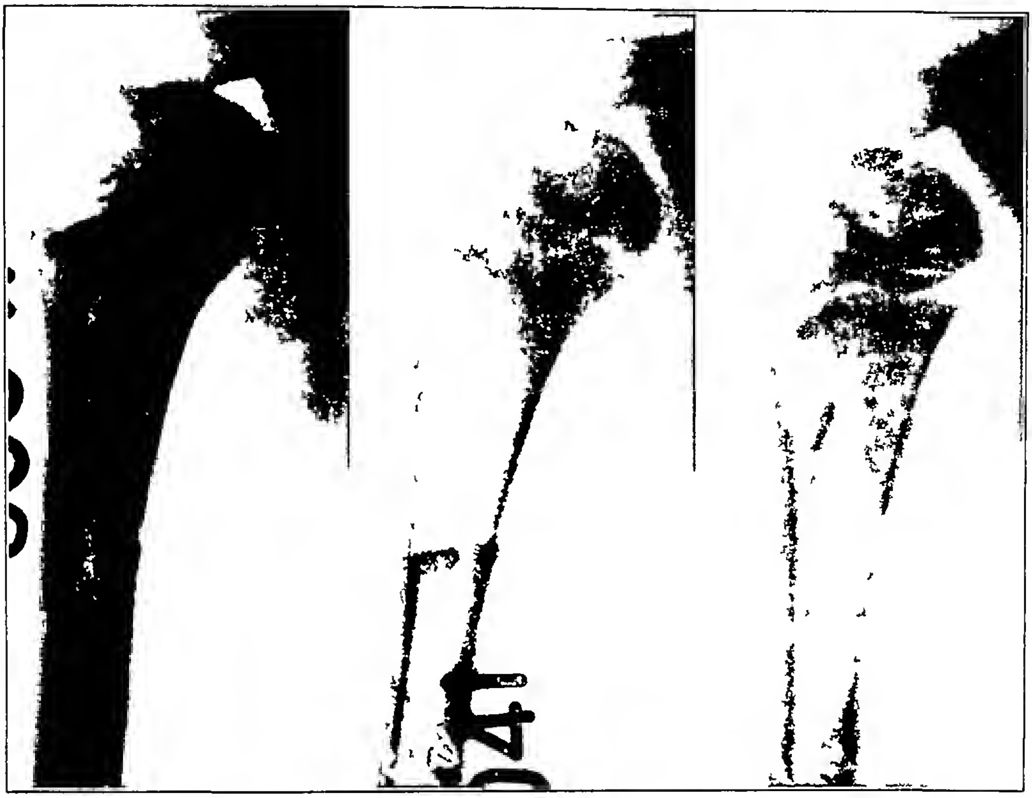

Fig. 1-D Fig. 1-E Fig. 1-F

Fig. 1-G Fig. 1-H Fig. 1-I

Figs. 1-G and 1-H. In roentgenograms taken at seven and seven and one-half years of age, respectively, the first metaphyseal defect is disappearing, while the second lesion has traveled away from the epiphysis.
Fig. 1-I. At eight and one-half years of age, the first metaphyseal defect has completely disappeared. The second defect remains large.

FIG 1-J FIG 1-K FIG 1-L FIG 1-M FIG 1-N

Fig 1-J At nine years of age, bone trabeculae are partially filling the second metaphyseal defect, which is still large and has sclerotic walls A third metaphyseal defect may be seen, arising from the same site as the previous two

Fig 1-K At nine and one-half years of age, the second metaphyseal defect is still apparent The third defect is very small and is already becoming obliterated

Figs 1-L and 1-M Roentgenograms taken at ten and eleven years of age show the third metaphyseal defect to be completely absent The second lesion is gradually disappearing

Fig 1-N At thirteen years of age no lesions are to be seen and the humerus appears normal

In 1936, when the boy was four years old, a small, well-rounded area of decreased density was noted in the upper humeral metaphysis (Fig. 1-B). In subsequent roentgenograms this lesion was seen to be enlarged, elongated in the axis of the shaft, and to have traveled away from the epiphysis with the growth of the bone. As it did so, its borders appeared sclerotic (Fig. 1-C). Later, its center became more dense, and, four years after it was first detected, this lesion had completely disappeared (Fig. 1-I). Meanwhile, when the child was five and one-half years old, a similar area of translucence was noted, beginning in the same location as the first (Fig. 1-D). This second defect became enlarged to a greater degree than the first. As before, its borders became sclerotic, later new-bone trabeculae filled in the defect, and by the time the boy was thirteen years of age, this lesion had disappeared (Fig. 1-N).

In Figure 1-J a third lesion may be seen, originating at the same site as the other two. The duration of this last metaphyseal defect was shorter, as it was no longer seen one year later (Fig. 1-L). Roentgenograms taken up to the time the patient was sixteen years of age failed to show any new lesions.

At no time did the patient have complaints referable to his arm, nor was there any history of trauma to the region. He had no *café au lait* spots, and no neurofibromata were found on physical examination. Because of the obvious benignity of these defects, no treatment was instituted.

Biopsy of the lesions was not done. However, the roentgenographic features are identical with those found in many metaphyseal defects seen in this Hospital which, at biopsy examination, were found to be filled with fibrous tissue. In some instances this fibrous tissue contained foam cells, small giant cells, and new-bone formation. Clinical symptoms are frequently absent. Jaffe and Lichtenstein, Hatcher, and Schlumberger have all described similar lesions, with correlation of the roentgenographic and pathological findings. There is no reason to doubt that the defects in the case presented belong to the same category.

The three metaphyseal defects in this case all appeared in the same area of the humerus. This indicates that they were due to a localized, intermittent disturbance in the process of ossification, as Hatcher contended. Each of the defects followed a similar course, and, as their borders became sclerotic, they migrated toward the diaphysis, finally disappearing in a period of from one to seven and one-half years. The natural course and the fact that they all originated from the same area would appear to be strong arguments against Jaffe and Lichtenstein's belief that they represent benign tumors formed from marrow connective tissue.

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EXTERNAL SKELETAL FIXATION IN THE TREATMENT OF FRACTURES OF THE TIBIA *

BY JOHN R NADEN, M D , VANCOUVER, BRITISH COLUMBIA, CANADA

The work covered by this review was done largely on the Orthopaedic Service of the Vancouver General Hospital Many factors have been responsible for the large number of cases treated with external skeletal fixation Apart from the fact that external fixation has a definite place in orthopaedic and traumatic surgery, its use has shortened the patients stay in the Hospital and thus aided the universal shortage of hospital beds

Steinmann pins and plaster in the treatment of fractures of the long bones had been used in Vancouver General Hospital for a number of years prior to 1942, with satisfactory results Although this method was not employed on all fractures, we had sufficient experience to appreciate its efficiency and usefulness, as well as the possible complications

In June 1942, we commenced using the external skeletal-fixation equipment devised by Roger Anderson This paper is a review of our experience with this method of treatment From June 1942 until the present time, external skeletal fixation has been used in over 950 fractures and orthopaedic conditions In this series almost 4,800 pins have been inserted†

Particularly on the coast of British Columbia, post-traumatic arthritis has been prevalent This problem had been encountered during all types of treatment of a great many fractures, and our feeling was that the incidence of arthritis might be lessened if the joints could be kept mobile instead of being fixed for a prolonged time A comparative statistical review, for this and other areas, of the period of fixation required for the solid union of fractures is not available, but it is our impression that union in this area is a little slower than the average, regardless of the method by which the fracture is treated

A total of 237 tibiae have been treated by this method These include fractures of all parts of the bone, in which our experience has shown that external skeletal fixation is an efficient method of treatment

The method of inserting the pins has varied only slightly Practically all of the pins have been inserted with a hand chuck This may be considered a slow and antiquated method, but the author has always been able to insert the pin in the desired position without too much difficulty By this procedure there is much less danger of thermal necrosis, and, as far as I have been able to determine, no case of ring sequestra has resulted from this cause

The placement of the pins is very important, the more obtuse the angle of the pins in each unit, the better the fixation in the bone and the less the possibility of the pins becoming loose When this has been difficult on account of the position of the fracture, an extra pin has been added to prevent side slipping No complications have resulted from the insertion of extra pins, and the motto has been "'Tis better to add a pin than have one too few" With a short upper fragment, into which the upper pin cannot be placed obliquely, the pin may become loosened and allow some side motion of the bone An extra half-pin inserted at a wide angle, probably almost anteroposterior, but possibly at a right angle, to the shaft, will give added fixation

In the great majority of fractures of the middle of the shaft, the proximal and the distal pins have been through-and-through,—that is, the proximal pin in the proximal fragment and the distal pin in the distal fragment The other two have been half-pins and whenever an extra pin has had to be added, it has been a half-pin

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 28, 1948

† Since the compilation of the statistics for this review, an additional twenty tibiae have been pinned. Approximately 300 additional pins have been inserted in fifty-seven fractures of all types

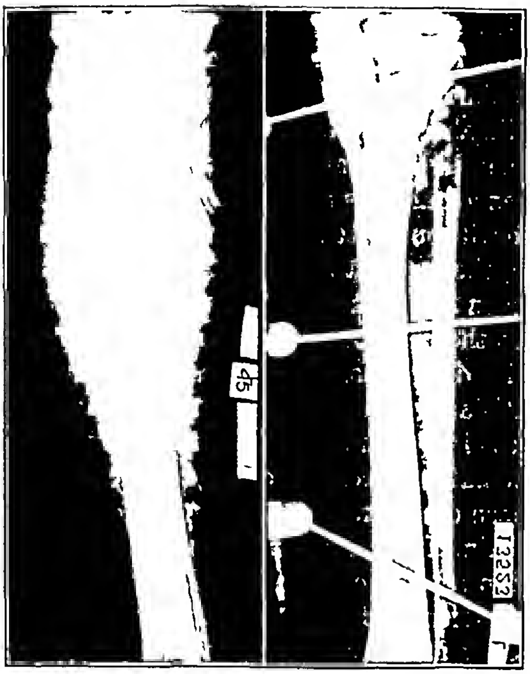

Fig 1-A
October 7, 1945

Fig 1-B
October 9, 1945

Fig 1-C
February 2, 1946

Figs 1-A and 1-B Case 119 Showing a severely comminuted fracture of the left leg, a compound, comminuted fracture of the right leg was also present The patient's general condition contra-indicated any attempt to obtain a perfect reduction, and it was thought unwise to attempt to correct the posterior angulation by any further manipulation

Fig 1-C Union had occurred at sixteen weeks

Fig 1-D The result two years later

Fig 1-D
January 2, 1948

Originally, we treated almost all fractures, except those of the femoral neck, as emergencies At the present time, a great many of the fractures, with the exception of those which are compound or complicated, have been treated as elective cases, and adequate general and local preparation has been given prior to the reduction and fixation

The cases to be illustrated are those in which, with two exceptions, external skeletal fixation alone has been used It had been felt that this discussion should not be complicated by the presentation of cases in which both internal and external fixation had been used In a certain number of cases where open reduction has been indicated, we have used a combined method of fixation, and a combination of internal fixation with screws or nuts and bolts, as well as the pins and external bars

The proportion of patients upon whom we have been doing a combination of open reduction and pin fixation has been increasing, but internal fixation has not necessarily been employed in all of these cases

In the simple fractures, the pins are inserted after the usual preparation and with rigid technique, usually with an assistant putting traction on the foot The importance

of traction during the insertion of the pins is that, if there has been much shortening, there will not be a variation in the skin tension after the fracture has been reduced.

After the pins have been inserted, small zephiran-soaked gauze dressings are spiked over the pins and held with sterile sheet wadding, and often a compression bandage is applied from the toes to below the knee. The clamps and bars are attached to the unit and then the connecting bars are added. Experience has shown that no attempt should be made to look at the fracture with the fluoroscope without putting the limb in the reduction frame. After the leg has been fixed in the frame, the connecting bars are released and the fracture is inspected. The room is darkened as soon as the dressings have been applied, so that the operator's eyes may become adapted to the dark in preparation for fluoroscopy. No attempt is made to reduce the fracture under direct vision. It is inspected only with a minimum of exposure. When reduction is satisfactory, the connecting bars are firmly fixed, and the leg is removed from the frame. It is important that the knee and the ankle be put through a full range of motion before the patient leaves the operating room.

In the care of compound fractures, it has been our plan to do a thorough cleansing of the entire leg and adequate preparation of the skin. The compound wound, if possible, is blocked off with a dressing, bandaged in position after the cleansing. The pins are then inserted, the dressing is carried out as previously described, and the units are completed. The compound wound is then debrided, if possible and if it is considered advisable, the wound is closed primarily without drainage. Few patients have had delayed primary closure, the great majority with compound fractures having been admitted within a short time of the injury and having been treated within a few hours.

The after-care has been largely that of "judicious neglect" as far as the pins are concerned. The dressings have been changed only when absolutely necessary, and then only by the surgeon. Active knee, ankle, and foot movements are required. Ambulation with crutches is started the day after fixation if at all possible, and the patients are sent home.

In none of the patients has early full weight-bearing been encouraged. We have often suggested that the patient wear a shoe and start putting the foot to the ground with some weight-bearing.

Routine roentgenograms are taken before discharge from the Hospital and at ap-

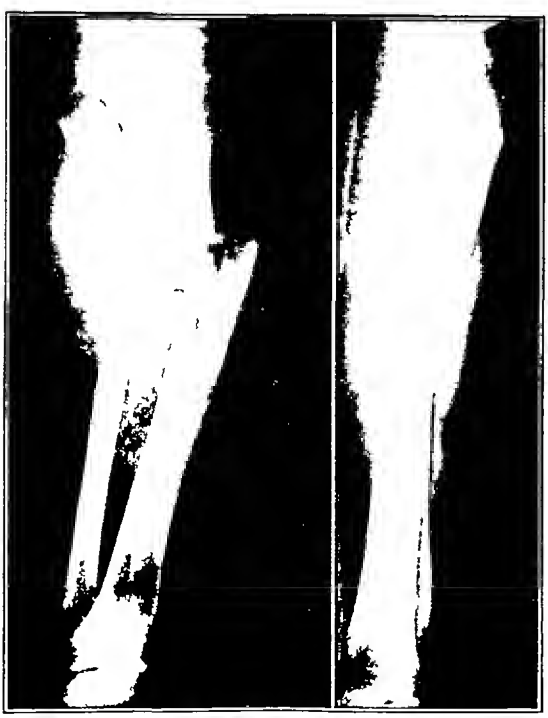

FIG. 2-A
October 7, 1945

FIG. 2-B
November 19, 1945

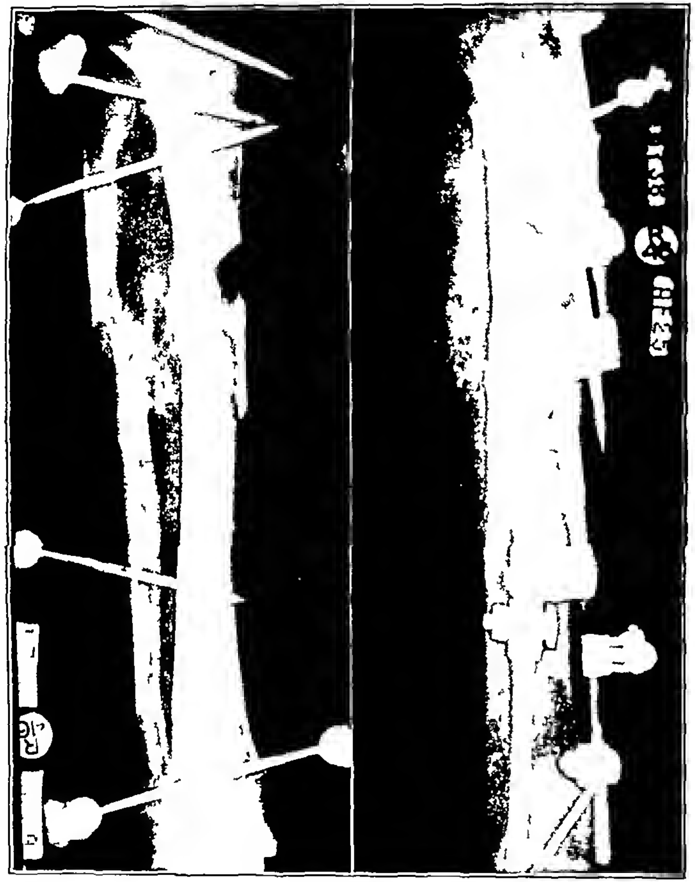

Fig 2-C
April 25, 1946

Fig 2-D
April 25, 1946

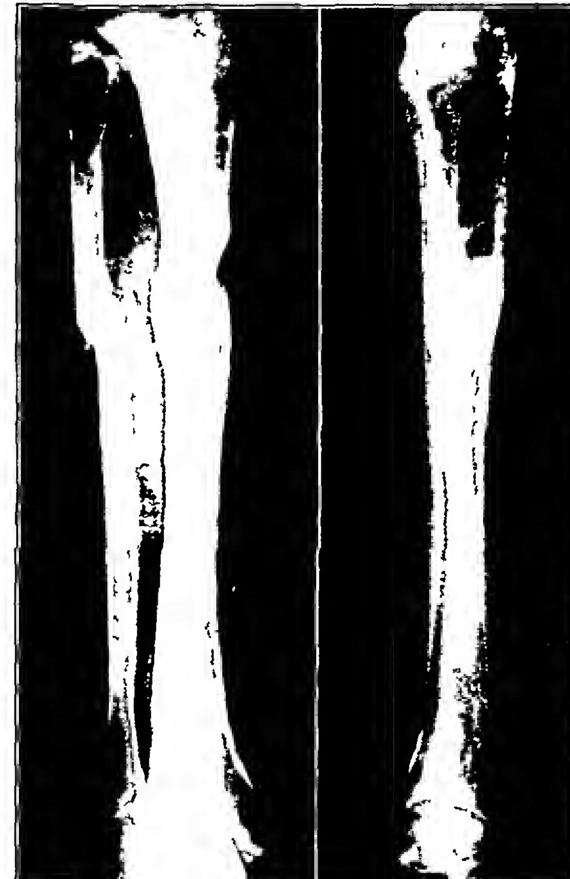

Fig 2-E
January 2, 1948

Fig 2-A Case 120 The right leg of the patient in Case 119 sustained a badly compounded fracture with loss of a large fragment
Fig 2-B The wound was closed over the fracture, but it was not possible to appose the margins throughout This was done by a secondary closure
Fig 2-C At the end of twenty-eight weeks, the bones had united
Fig 2-D An oblique view shows the apparent difference in the "filling in" of the gap
Fig 2-E Two years later the patient, an eighty-year-old man, was able to walk several miles without difficulty

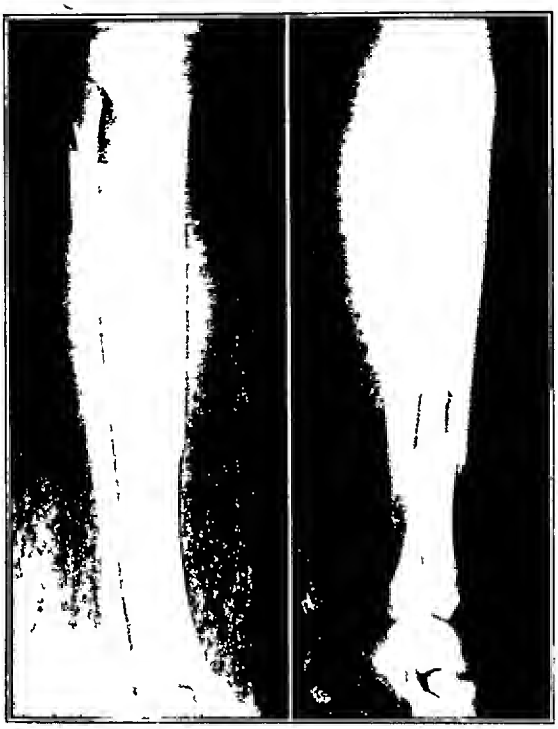

FIG. 3-A
March 3, 1946

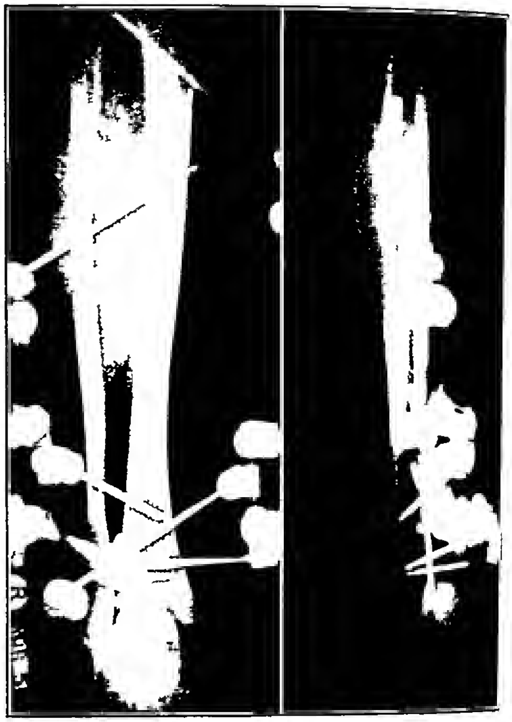

FIG. 3-B
March 5, 1946

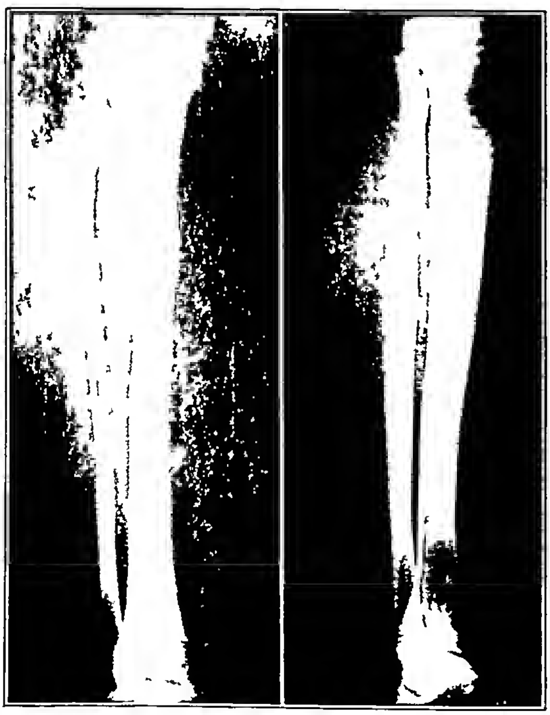

FIG. 3-C
January 2, 1948

Fig. 3-A: Case 142. This patient had a skiing accident.

Fig. 3-B: Roentgenograms taken after reduction demonstrate the use of extra half-pins in the short distal fragment below the spiral fracture.

Fig. 3-C: Shows the result almost two years later.

proximately monthly intervals thereafter. If there is a tendency to absorption and the appearance of over-extension, the connecting bars are loosened and then tightened. If the roentgenograms look satisfactory at the end of ten to fifteen weeks, the connecting bars are released and the fracture is tested clinically. If there is still a slight amount of spring at the fracture site, the connecting bars are again fastened, and if there are no contra-indications, the patient may be advised to discard the crutches and have full weight-bearing with the pins still in position.

Representative cases demonstrate the various types of fractures, before and after operation, with x-rays of the end results.

Table I summarizes the work covered by this review. There have been only two instances of non-union among the cases of simple fracture. One patient (Case 139) had fractures of the ulna, the pelvis including the sacrum, and the tibia; the fracture of the tibia included the ankle as well as the shaft. The second non-union occurred in a patient (Case 161) who had long-standing disability of the leg, resulting from poliomyelitis. He had been struck across the back of the leg by some rolling logs, with a resulting large hematoma of the calf and with fractures of the ankle as well as of the shaft. Union took place in the

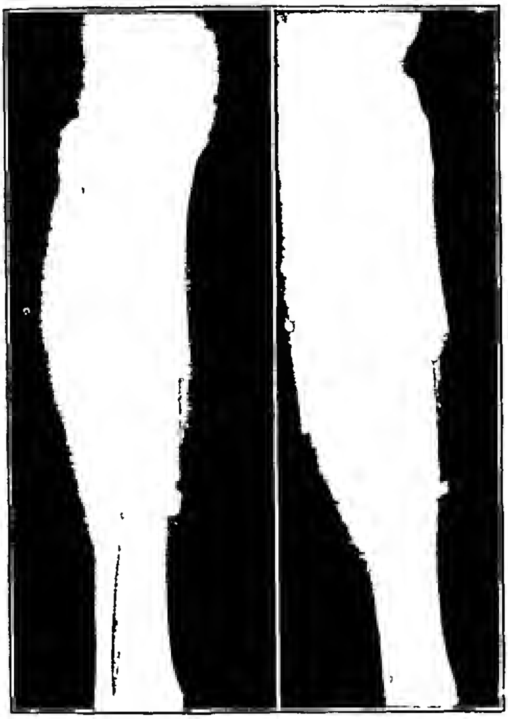

FIG 4-A
September 28, 1945

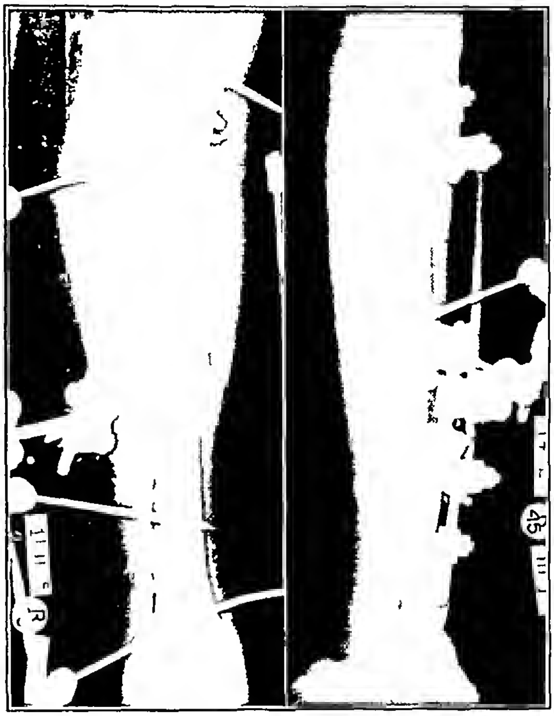

FIG 4-B
October 18, 1945

Fig 4-A Case 121 Showing a very severely comminuted but not compounded fracture

Fig 4-B Demonstrating the possibilities of this method, although the technical result is not perfect

Fig 4-C Showing the appearance of the leg almost two and one-half years later

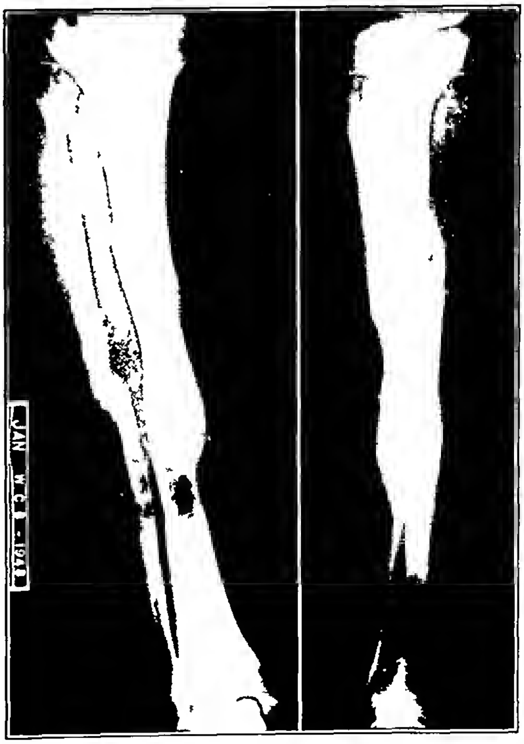

FIG 4-C
January 2, 1948

ankle in ten weeks After bone-grafting of the shaft, union occurred in twenty-eight weeks, but there was some necrosis of the skin over the operative area

Early bone-grafting was done in four cases, including Case 212 (Figs 5-A and 5-B) In Case 168, a pin clamp had broken a month after the original pinning and the fracture had become badly displaced It was thought advisable to remove the pins, allow the pin site to heal, and then to do an open reduction and bone-grafting with re-pinning

Minor local skin irritation about the pins occurred in about 5 per cent of the patients In none of these was there any definite infection or bone involvement The areas healed almost immediately and the pins were removed, in most of them, healing was complete at the time the dressings were removed, in one week

The second classification of skin difficulty was present in those who had definite infection about the pins, but without infection of the bone Five patients required hospitalization for a few days on this account

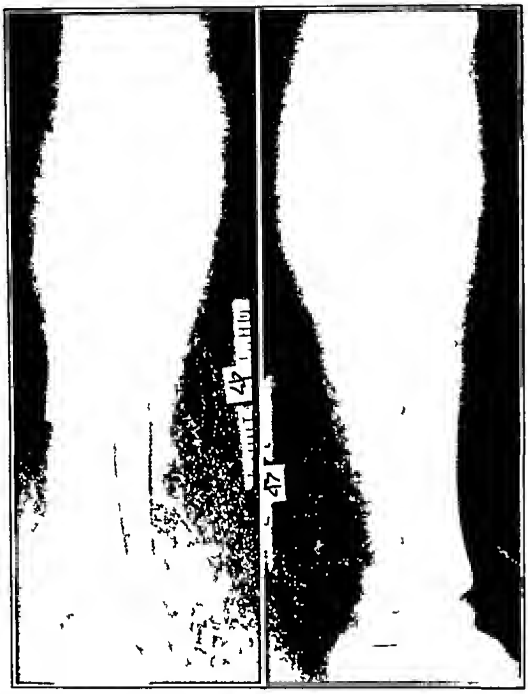

FIG. 5-A
May 26, 1947

FIG. 5-B
December 23, 1947

Fig. 5-A. Case 212. A logger, who had been struck by a falling log, was admitted four days after the injury. Roentgenograms show the tremendous swelling and large bleb formation. The fracture was not compound, but there was some loss of sensation and movement, thought to be the result of the severe contusion with swelling. Any immediate interference was contra-indicated. It was three and one-half weeks before the skin was in satisfactory condition to proceed with fixation.

Fig. 5-B. An extra half-pin was placed in each fragment for firmer fixation. This case is an example of early bone-grafting in fracture of the tibia, with external skeletal fixation. Roentgenograms show the appearance twenty-eight weeks after grafting; the loss of sensation and movement is now felt to have been due to ischaemia, which developed prior to our seeing the patient.

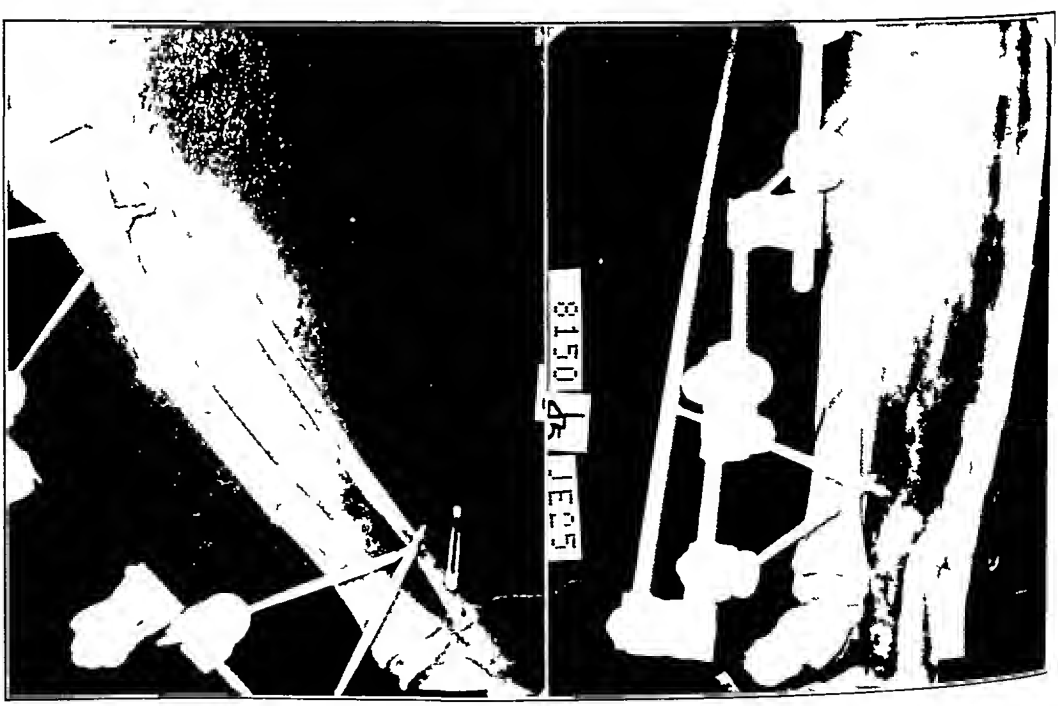

FIG. 6-A
June 25, 1945

Case 105. A four-year-old girl was run over by a truck. The skin of the leg, from the knee to the ankle, rolled off in a large flap with the exception of that on the posterior quarter, where it was attached. It was thought at first that amputation would be necessary and that the child's condition did not warrant even roentgenograms. After thorough cleansing, it was demonstrated that the central fragment was lying loosely in a sleeve of periosteum; actually, the piece was removed from its bed when it was being

(Continued on page 593)

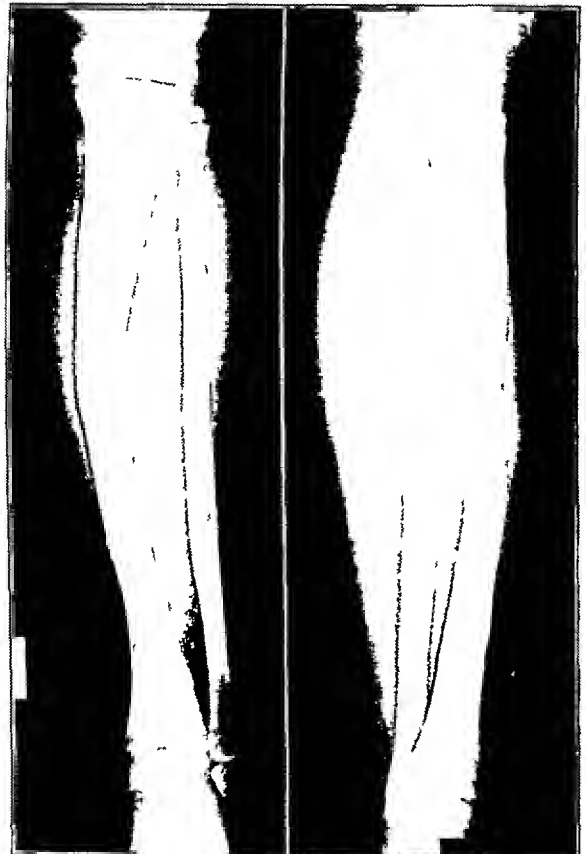

Fig 6-B
January 27, 1946

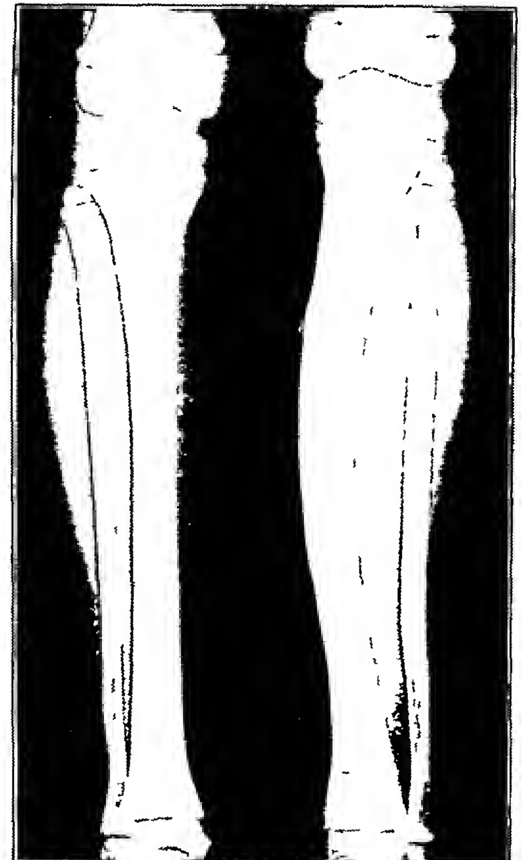

Fig 6-C
December 5, 1947

Fig 6-D
December 5, 1947

realigned, and was held in the air with forceps The skin flap started just posterior to the fibula and was turned anteriorly and medially It was not possible to put in through-and-through pins, and even when the check roentgenograms showed the angulation, it was thought unwise to attempt to alter the position The fractures were united in ten weeks All of the skin flap had "taken" except a small corner over the inferior part of the fibula, and that was treated by skin-grafting Revascularization was slow

Fig 6-B Six months later, the girl had the misfortune to slip and to fracture the central fragment The blood supply was still too uncertain for an attempt to be made to correct the angulation at that time

Figs 6-C and 6-D Comparative anteroposterior and lateral views of both tibiae show sufficient revascularization to allow for a corrective osteotomy Note the overgrowth of the fractured left tibia, shown in Fig 6-C

Fig 7-A
November 28, 1944

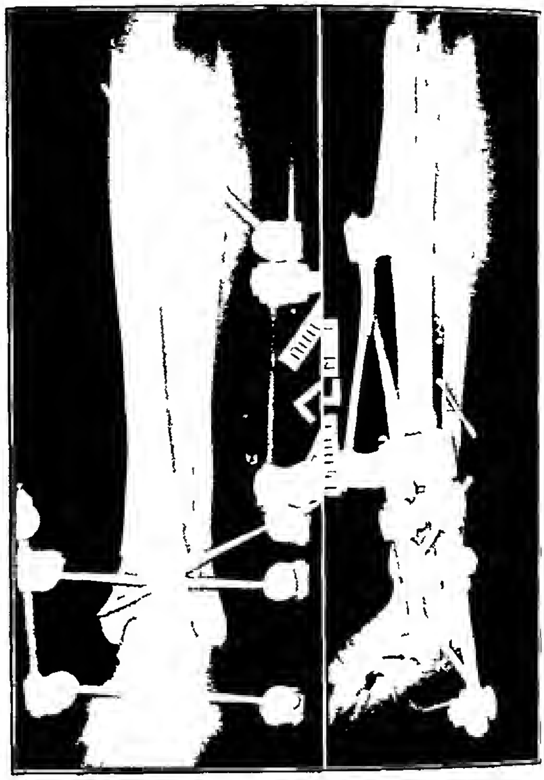

Fig 7-B
November 29, 1944

Fig 7-A Case 64 This patient had a comminuted fracture of the lower quarter of the leg, not involving the joint
Fig 7-B A pin was put through the calcaneus as well, on account of the very short fragment
Fig 7-C Roentgenograms taken over three years later The patient had no disability
Fig 8-A Case 166 A woman, seventy-five years old, fell on the stairs The original roentgenogram did not give the impression of the large posterior lip fragment, but an attempt at closed reduction demonstrated the lack of stability

In the third classification of pin difficulty, there was definite bone involvement Four patients (Cases 20, 29, 44, and 151) (Fig 9-A) showed small sequestra about pin sites After removal of the pins the areas healed immediately, without residual disability, none of these were ring sequestra, but just small flakes about the size of rice One patient (Case 27A) had some low-grade infection in the head of the tibia with slight persistent drainage, but otherwise with good function

One patient (Case 186) had sloughing of tissue of the peroneal group of muscle without apparent infection about the pins and without bone involvement This patient had a definite lesion of the external popliteal nerve There have been several transient lesions of the external popliteal nerve, they may have been due to too tight bandaging

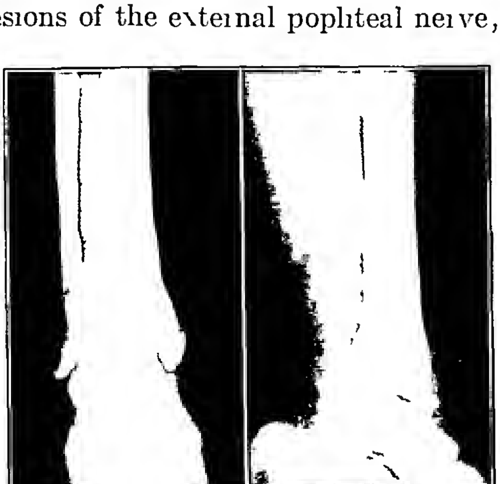

Fig 7-C
January 7, 1948

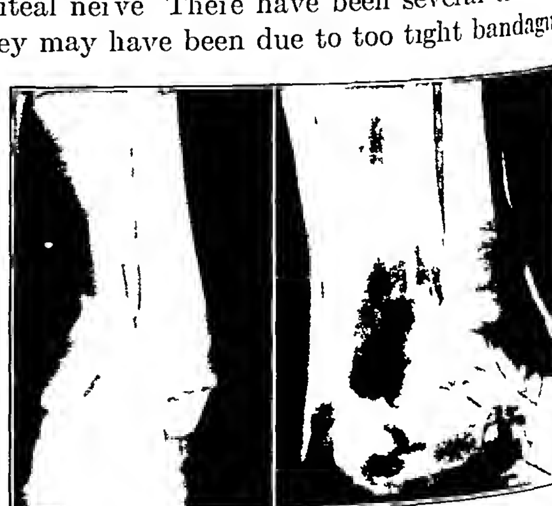

Fig 8-A
[illegible] 1946

TABLE I

TIBIAL FRACTURES TREATED BY EXTERNAL SKELETAL FIXATION

Total number of cases	237
Still under treatment (too early for end result)	31
Cases with end-result rating	206
Simple fractures	
Upper third	26
Middle third (approximately middle three-fifths)	90
Lower third without ankle involvement	16
Lower third with ankle involvement	24
Compound fractures	
Middle third (approximately middle three-fifths)	35
Lower third involving ankle	7
Ununited shaft fractures (simple and compound) pinned previously	8
Open reduction	
Without internal fixation	26
With internal fixation	32
Non-union	
Previously pinned simple shaft fractures	2
Previously pinned elsewhere	2
Compound fractures of the shaft	4
Bone-grafting for cases of non-union previously treated elsewhere	11

local swelling, or the close proximity of a pin to the nerve Recovery occurred in all cases

One patient (Case 134) had a spiral fracture of the lower end of the tibia in 1945, without involvement of the joint Pinning was done within two hours of the injury An extra pin was added because of the very short fragment Twenty-four hours later, the patient had a sudden severe pain in his leg, the pulsation of the posterior tibial nerve was absent, and the foot was cold Exploration of the vessel as far as the bifurcation was of no avail, and amputation was necessary later Examination of the vessel after amputation showed that it had been damaged from the fracture downward, especially above the site of pin insertion

In addition to Case 212 (Figs 5-A and 5-B) there was one other patient with ischaemia This patient had a severely comminuted fracture of the shaft below the head with severe swelling, but without a great amount of pain In retrospect, it is apparent that the fascia should have been incised

FIG 8-B
November 13, 1946

FIG 8-C
January 3, 1948

Fig 8-B Ten weeks later, roentgenograms showed the reduction and fixation obtained by the closed method

Fig 8-C Sixteen months after the accident there was a full range of motion, and the patient stated that she had no disability

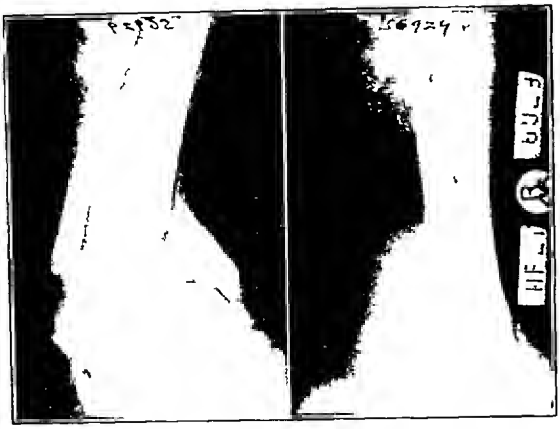

Fig 9-A
April 27, 1946

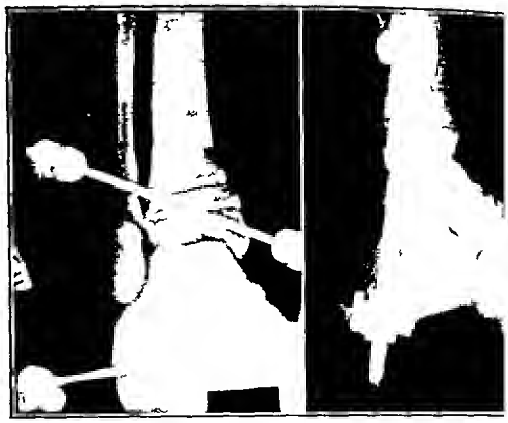

Fig 9-B
May 2, 1946

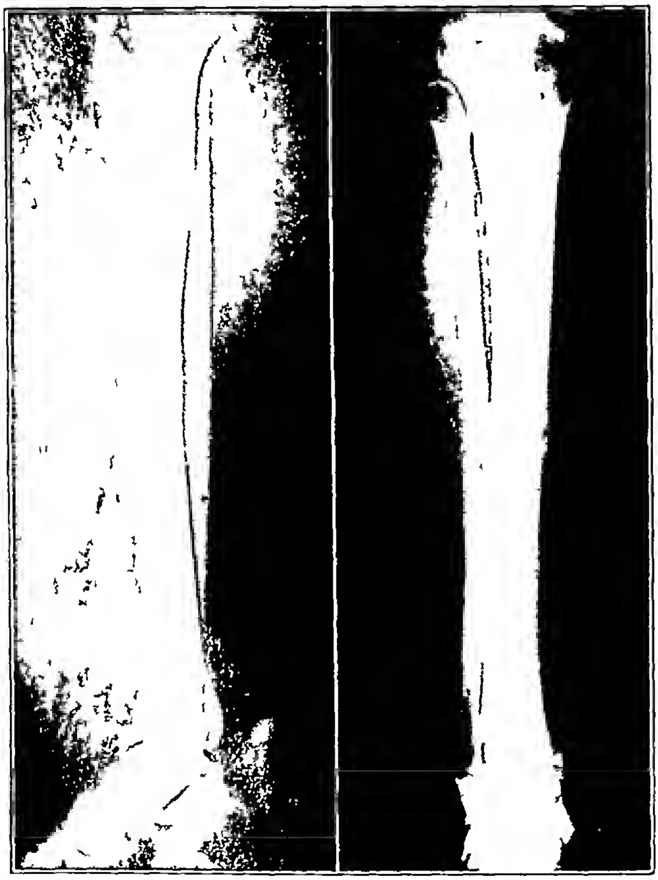

Fig 9-C
October 7, 1947

Fig 9-A Case 151 An attempt at closed reduction was made on the ankle but it was not successful, due to interposition of some small fragments

Fig 9-B After skeletal fixation the roentgenograms showed satisfactory reduction There was union in thirteen weeks, the patient going back to work in good time

Fig 9-C Eighteen months after the injury, the patient had a small swelling over the middle of the tibia Roentgenograms show a small sequestrum overlying the exit point of a half-pin This was removed in the office through a small incision, and the area healed immediately The end result has been very satisfactory

Four patients with badly co minuted fractures involving the a kle had severe residual trauma arthritis, and arthrodesis was quired External skeletal fixati was employed after operation these cases

Four cases of non-union curred among the thirty-five co pound fractures of the shaft Ma of the fractures in this group w severely compounded and comm nuted, and in some there was lo substance The great majority of the compound wounds healed by first intention spite of this, however, the operative wounds broke down after bone-grafting in thi instances (Cases 25, 125, and 152)

Two compound fractures, primarily treated with pins, were so severe that amputati was necessary eventually In one (Case 8) there was loss of a large portion of the lo tibia, a large area of skin damage and severe soft-tissue damage, and a nerve lesion the second (Case 171), another very severe fracture involving the lower half of the sh and the ankle, pins were inserted four weeks after the injury, in an attempt to maint length and allow for some skin coverage A flare-up of infection necessitated a guillot amputation In a third (Case 79), an old ununited compound fracture about the ank which was originally infected but had healed, a bad recurrence of infection after bo grafting made later amputation necessary

An attempt has been made to give a complete analysis of all the cases with an end-result grading.* One hundred and ten cases were rated $A_4F_4E_4$.† In these cases there was no appreciable shortening, and joint function was through practically a full range; there was only occasional joint pain and no disability. In an analysis of the end results, the good as well as the nearly perfect results were classified in the 4-4-4 rating. These patients have had roentgenographic proof of alignment with films of the knee and ankle joints in almost all cases. The limb lengths were not checked by comparative roentgenograms of the opposite extremity, but only by manual measurement. The 110 cases included seventy closed fractures (simple and complex) and twenty-one compound fractures of the shaft. Five were fractures of the tibial head, involving the joint. Ten cases involved the ankle joint. Four were cases of non-union of the shaft in which bone-grafting and pinning was done.

Very few patients had an appreciable amount of shortening. There was a definite tendency in the early cases toward getting over-extension at the first reduction. This necessitated allowing the fracture to close by loosening the clamps and then tightening them. There was appreciable shortening—that is, over one-quarter of an inch—in only five cases, and these were cases in which there was loss of bone substance. One patient (Figs. 6-A and 6-D) had definite increase in length due to incomplete reduction and associated overgrowth, apparently from fracture hyperaemia.

The general alignment of the fractures has, on the whole, been satisfactory. Two patients had lateral bowing and two had slight posterior bowing, but neither of these conditions was severe enough to require further interference. As mentioned previously, malposition resulted in Case 168 from a broken clamp which was not discovered until one month after the original reduction. In Case 59, the patient had a fracture in the lower quarter with malunion in external rotation due to a poor "technical job" at the time of the original reduction; this was later corrected by a rotation osteotomy, and the end result was excellent.

There were twenty-six fractures of the proximal end of the tibia, twenty-five of which involved the joint. In five the end-result rating was $A_4F_4E_4$. Six patients had tears of the lateral menisci, which were excised. In fifteen of the twenty-one cases, motion of the knee was restricted; three had flexion of less than 90 degrees and the remainder had flexion of 90 degrees or more. Eleven patients had some degree of traumatic arthritis. Three had definite knee-joint relaxation, but none of the knees required arthrodesis.

In thirty-one cases the ankle joint was involved. Seven of these were compound fractures, many of them severely comminuted, with multiple fractures into the joint. Ten of the thirty-one cases had an end-result rating of $A_4F_4E_4$. The three patients with ankle involvement requiring amputation and four requiring ankle arthrodesis have previously been mentioned in the text. Of the remaining fourteen cases, seven had definite ankle arthritis with restriction, one had ankle and knee restriction, and six had some ankle pain.

Of the entire group, twenty-five patients had ankle arthritis and twenty-seven had arthritis of the knee, either alone or combined with restriction. Of this number, ten patients had knee and ankle arthritis, either alone or accompanied by restriction.

The average length of time required for union of the simple shaft fractures was sixteen and one-half weeks; for twenty-eight compound shaft fractures it was sixteen weeks. Union was delayed in eight simple or complex fractures, ranging from twenty-four to thirty-eight weeks. Five compound fractures required from twenty-two to thirty-four weeks for union.

* The review and the grading of the cases from 1942 to 1945 were done by Dr. Giles B. Murphy of the Workmen's Compensation Board of British Columbia.

† The symbols of end-result rating commonly used in the Massachusetts General Hospital, Boston, have been employed. "In each instance the result was evaluated from the separate viewpoint of anatomic restoration (A), functional recovery (F), and effect upon economic ability (E) and was graded on a numerical basis in respect to each of these criteria. The numbers used ranged from 4, the maximum, down to 0." [1]

The average period required in the Hospital after operation was eight days for the simple fractures, for the twenty-eight compound shaft fractures, uncomplicated by other severe injury, it was sixteen days

When the nineteen patients with non-union (including thirteen originally treated elsewhere) had been treated by bone-grafting and pin fixation, union occurred in twelve to twenty-two weeks in nine cases In four cases union required twenty-six weeks, in five, twenty-eight to forty-eight weeks One patient had a severe flare-up of infection and amputation was required

Associated injuries included three severe head injuries, two of which resulted in the death of the patients, one definite nerve injury, associated fractures,—five of the calcaneus, nine of the pelvis, seven of the femur, four of the forearm, and two of the spine One patient had bilateral dislocation of the hip with fractures of the pelvis, humerus, and clavicle There were a number of other associated complications Of three patients with known fat emboli, one died Two cases were complicated by pre-existing poliomyelitis

CONCLUSIONS

This review presents our experience with external skeletal fixation in the treatment of 237 fractures of the tibia, from a total of over 950 cases in which pinning was done for all types of fractures and orthopaedic conditions In spite of the difficulties encountered, we are still using this method

1 MASSACHUSETTS GENERAL HOSPITAL FRACTURE SERVICE (P D Wilson, Editor) Experience in the Management of Fractures and Dislocations (Based on an Analysis of 4390 Cases) Philadelphia, J B Lippincott Co , 1938

DISCUSSION *

DR MATHER CLEVELAND, NEW YORK, N Y (Chairman) Dr Naden prepared a good deal of this paper while he was undergoing surgical treatment, and he deserves tremendous credit for his willingness to participate in this symposium We are also obliged to his surgeon for permitting him to be present

If this method of treating fractures is as good as its proponents say, all fracture surgeons should know more about it Our Committee on Fractures and Traumatic Surgery is at present, with the full cooperation of our fellow member, Roger Anderson, attempting to study the use of external skeletal fixation in the treatment of fractures Its use in Army hospitals, as I saw it, was attended with too many complications, such as delayed union, pin-hole infection, and often osteomyelitis The pins were at times inserted without regard for the anatomical structures between bones and skin, with an occasional disastrous result The widespread use of this method had to be prohibited, and the apparatus was withdrawn from all except a few hospitals, staffed by competent fracture surgeons, who were allowed to use it where it seemed to be definitely indicated The external skeletal-fixation splints are not to be entrusted to the inexpert or inexperienced doctor Even in the expert hands of Dr Naden, several popliteal-nerve injuries and 5 per cent of soft-tissue infections or "local irritations" were noted

Dr Naden has given some points in technique which should be heeded He states that he has had no more sequestra which could be attributed to thermal necrosis of bone He has been utilizing open reduction and internal fixation, in addition to external skeletal fixation, in an increasing number of patients Here we see utilization of two methods under discussion today, to emphasize the point that no one method will answer for all fractures The one obvious advantage of this method is the short period of hospitalization However, I believe we should know more fully how comfortable these patients are after leaving the hospital within ten days of some of these major injuries

This is an interesting series of fractured tibiae, and great ingenuity has been shown in their treatment Many of them were serious problems from the time of onset, and in two cases of compound fracture, amputation was required eventually

A great deal of additional data, such as function of the adjacent joints, wound healing, and time of bone healing, could be extracted from this wealth of material

DR H EARLE CONWELL, BIRMINGHAM, ALABAMA Dr Naden's report of 206 fractures of the tibia treated by external pin fixation, is probably the largest series presented by an individual surgeon In some of the cases shown by Dr Naden, the pins are dangerously near the joint, and it would seem to me that such

(Continued on page 613)

* The rest of this discussion was published in *The Journal* in January 1949, with the paper by Edward M Winant, M D , and that by Harrison L McLaughlin, M D , and his associates

PATHOLOGICAL CHANGES FOUND IN MATERIAL REMOVED AT OPERATION IN LEGG-CALVÉ-PERTHES DISEASE *

BY SAMUEL R. HAYTHORN, M.D., F.A.C.P., F.P.A.C., PITTSBURGH, PENNSYLVANIA

From the William H. Singer Memorial Research Laboratory of the Allegheny General Hospital, Pittsburgh

In 1941, Steele reported a series of cases of osteochondritis deformans juvenilis (Legg-Calvé-Perthes disease) in which he had performed operation in the hope of hastening healing and shortening the period of disability. He reasoned that, if the debris of the necrotic tissue were removed, the head were filled with healthy bone grafts, and the extremity were put at rest, healing would take place rapidly. His operation consisted in opening the joint and cutting a door, approximately one-half inch long and one-quarter inch wide, in the superior anterior surface of the head and neck, so that the opening crossed the epiphyseal line. He chose the superior anterior surface so that, if any interference occurred, it would result in coxa valga instead of coxa vara. He curetted out the degenerated tissue through this door, packed the cavity with bone curls from the femoral neck, and closed the wound. Following the operation, the patient was kept at rest in bed with a lightweight extension for at least three weeks, and then was allowed up on crutches. In most of the cases, the period of regeneration was reduced to about six months and the results were satisfactory.

The material upon which this pathological report is based was obtained by curettement of the head of the femur in thirty-six patients, operated upon in the Orthopaedic Department of the Allegheny General Hospital.** Thirty-three cases were considered clinically, pathologically, and roentgenographically to be Legg-Calvé-Perthes disease, one proved to be a very early osteogenic sarcoma, one was an early osteomyelitis following injury, and one was complicated by bilateral dislocation of the hip. In addition, material curetted from the head of the femur in patients over twenty years of age was examined, and was found to differ from that seen in the average case of Perthes' disease by the absence of endochondral osteogenesis.

The point has been raised that the fragmentary nature of tissue obtained by curettement necessarily limits the interpretation of the relationship of the changes which existed within the femoral head before surgical removal. In a measure that is true, yet the pieces were large enough to determine the character of the lesions and the relative degree of pathological change. The opportunity to review and compare the lesions in thirty-three cases of the disease was unusual and partially offset other disadvantages.

As would be expected, the curetted material was not alike in all cases, even though it was made up of similar elements. Wider ranges and degrees of changes were seen than those described in reports of single cases. Many of the pieces could be identified by their histological structure, and could be used to postulate their probable positions in the original lesions. The reports of cases like those of Gall and Bennett and of Zemansky, where whole femoral heads were examined, were especially helpful in the theoretical reconstruction of our cases. Furthermore, with curettage there was no opportunity to examine the ligamentum teres for the vascular changes which have been described as having a causal relation to the necrobiosis.

ROENTGENOGRAPHIC FINDINGS

The roentgenographic findings are typical, although there is a discrepancy between the roentgenograms and the appearance of the femoral head when exposed at operation

* Presented at the Annual Meeting of the Association of American Pathologists and Bacteriologists, Philadelphia, March 12, 1948.

** Twenty-six cases were on the Service of Paul B. Steele, M.D., and ten on the Service of J. A. Heberling, M.D.

The usual roentgenographic findings, as described by Hodges, Phemister, and Brunschwig consist of flattening of the femoral head with fragmentation and sometimes cavitation of the ossification center The process may involve the epiphyseal line, causing the neck to become broader than normal Sometimes an oval area of reduced density develops in the lateral portion of the neck In untreated cases of long standing, the head becomes too large for the acetabulum, extends beyond it, and has the appearance of having been crushed by the acetabular rim The descriptions made at operation would indicate that the appearance of crushing was more apparent than real The head was not flattened as it appeared in the roentgenogram, but remained spheroidal, and the cartilage appeared normal except for thickening The gross appearance of the acetabulum was normal

Gill [7], who made extensive roentgenographic studies, divided the disease into a degenerative phase, lasting approximately one and one-half years, an abrupt turn in the cycle and the final regenerative phase, which is completed in from two to three years He found that the course could be shortened by rest and mechanical means, which take the pressure of weight-bearing off the hip In several of his cases the condition was discovered by roentgenograms before the onset of symptoms, and the earliest lesions seen were areas of necrosis in the metaphysis of the neck of the femur, manifested by irregular "holes" in the bone of the neck These usually appeared at the lateral margin of the epiphyseal cartilage, although the central and medial margins were occasionally involved Subsequent degenerative changes occurred in the head of the femur, the first region affected was that which directly overlay the degenerated area in the metaphysis Later, decalcification or so-called fragmentation, with isolated areas of increased density, appeared These finer changes were followed by those alterations in the size and shape of the head which are

FIG 1-A

FIG 1-B

Fig 1-A Case 1 In N T, a white boy, aged four years, symptoms had been present for two months before operation Diagnosis of Legg-Perthes disease was made clinically and roentgenographically The head is of the mushroom type A reaction resembling that of a benign giant-cell tumor came from the material curetted from this head Nothing resembling a bone cyst is seen in this roentgenogram

Fig 1-B This was the first patient operated upon by Steele, and bone grafts were not inserted at the first operation

Roentgenogram taken seven months after first operation As healing was not complete, the head was again curetted and bone grafts were driven in Healing followed Bone grafts from neck of femur were used in all other cases

Fig 1-C

Pathologically, this was grouped with ten other cases showing bone-cyst formation, and had the most pronounced symptoms in the group Note the very dense fibrous replacement in the marrow spaces, loss of polarity of the chondrocytes, and presence of osteoid tissue (× 175)

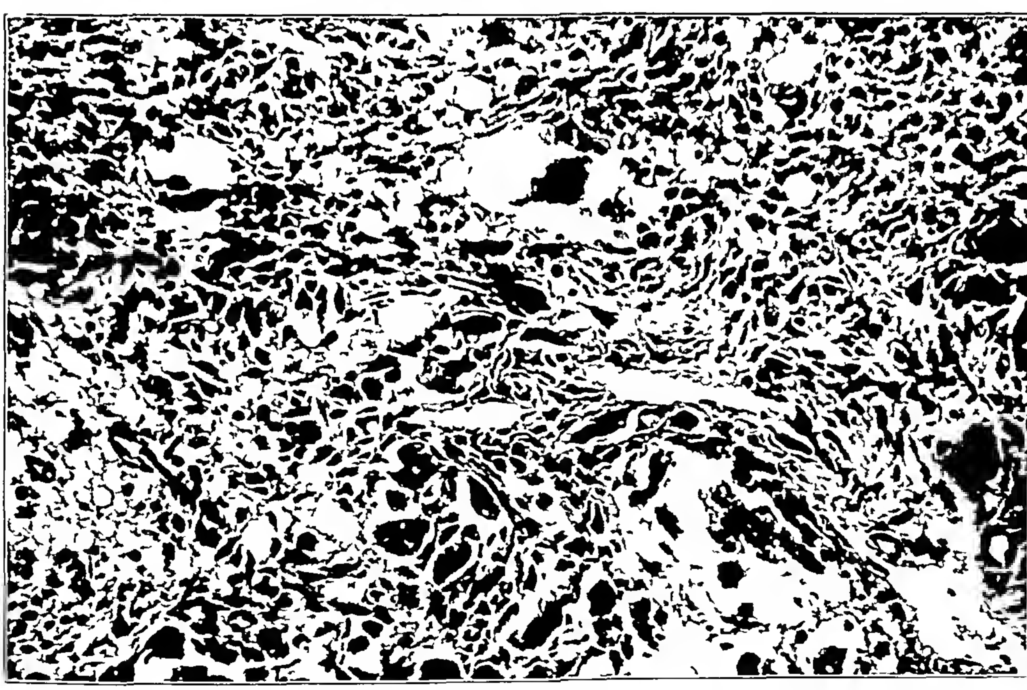

Fig 1-D

Several cyst walls contained areas resembling benign giant-cell tumors They were small and diffusely placed, and were backed up by bony spicules Note the fatty stroma, the generally parallel arrangement of the fibroblasts, and the multinucleated giant cell (× 175)

generally accepted as typical of the disease Gill's observations are interesting in light of the histopathological finding of small bone cysts, to be described later

Lipscomb and Chatterton, in 1942, by means of roentgenographic studies, described changes in the acetabulum which accompanied those of the head of the femur Gall and

Bennett verified the acetabular involvement in their report of a case with autopsy They found increased lacunar resorption of bone and irregularities in endochondral ossification Burrows stated that 10 per cent of the cases are bilateral, Hagen reported bilateral occurrences in each of two brothers, and suggested a familial tendency

In our series, the roentgenograms were typical of Legg-Perthes disease They showed variations in the amount of deformity and in the density of the femoral head, sometimes with considerable distortion of the head The heads often appeared to be flattened, sometimes with a mushroom or cap-shaped appearance When the joint was opened, the distortion and flattening were much less evident than the operator had been led to expect

MACROSCOPIC CHANGES

Zemansky, who reported a case of Legg-Perthes disease in which the femoral head was resected, described the macroscopic appearance as follows The cartilage over the head was thrown into folds with deep crypts between The cartilage was clear, white, and glistening In the depths of a crypt was a dark red area, suggesting hemorrhage The outermost portion of the cartilage was lifted from the underlying bone and hung in shreds Gall and Bennett reported a case with autopsy, and found that the head was flattened on the superior surface and covered with smooth, normal-appearing cartilage The acetabulum appeared normal, the synovial membranes showed slight villous hyperplasia, and the ligamentum teres was slightly flattened In Lippmann's case, flattening of the crest and grooves were present grossly, and the ligamentum teres protruded sharply from the fovea capitis It was swollen and oedematous

The gross descriptions in our cases were made at operation by the surgical assistant The majority of the heads were described as spheroidal, smooth, and glistening, and the cartilage was said to be unusually thin Some showed slight flattening with cartilage of uneven thickness, some were said to be slightly "eroded" Others were fragmented, and

Fig 2-A

Fig 2-B

Fig 2-A Case 3 R B, a white girl, aged five years, had had symptoms for about six months before operation The clinical, roentgenographic, and pathological diagnosis was Legg-Perthes disease Pathologically, the case presented all of the changes except bone-cyst formation

Fig 2-B Four months after operation, the condition was healed Shortening and thickening of the neck were present

FIG 3

Case 8 In L H, a white girl, aged seven years, symptoms began four weeks before operation Clinical and roentgenographic diagnosis of Legg-Perthes disease was made Pathologically, the case was grouped with the predominantly degenerative lesions The upper right portion shows marrow spaces, filled with necrotic material Two bony spicules are necrotic At the left and below are broken lines of osteogenesis In the left lower corner the chondrocytes have lost their polarity (× 135)

one or two were loosened In two or three instances, intracartilaginous cysts were mentioned The contents of the heads were described as cystic and as containing soft spots, necrotic material, and softened bony spicules Four cases showed hyaline cartilage, extending down the neck as far as the trochanter In one instance a band of inflamed connective tissue was found, attached to the neck In several cases small cystic areas were present in the neck, and evidence of bony absorption of the neck was mentioned twice No inflammatory processes were described in the soft tissues, and nothing was said concerning the ligamentum teres

In the laboratory, the tissue obtained by curettement was described as soft, necrotic, and as containing bony spicules and bits of cartilage The color of the contents was generally given as brownish-red All the curetted material had to be decalcified before being sectioned

HISTOPATHOLOGICAL CHANGES

In the thirty-three cases that were clinically, pathologically, and roentgenographically identified as Legg-Perthes disease, the microscopic changes followed a similar pattern Usually the biggest piece was cartilage, and could be identified as a part of the surgical door, removed at operation to gain entrance to the femoral head and neck In some of the cases the door was sent as a separate specimen, with a different number Smaller bits of cartilage, with degenerated areas on two sides, were accepted as portions of the epiphyseal cartilage Hemorrhage was a constant feature, but was discounted, since the material had been scraped out of the head or neck with a curette

It would involve too much repetition to give either the clinical histories or the pathological changes for each case The lesions will, therefore, be discussed, and the cases will be grouped according to the predominating changes found

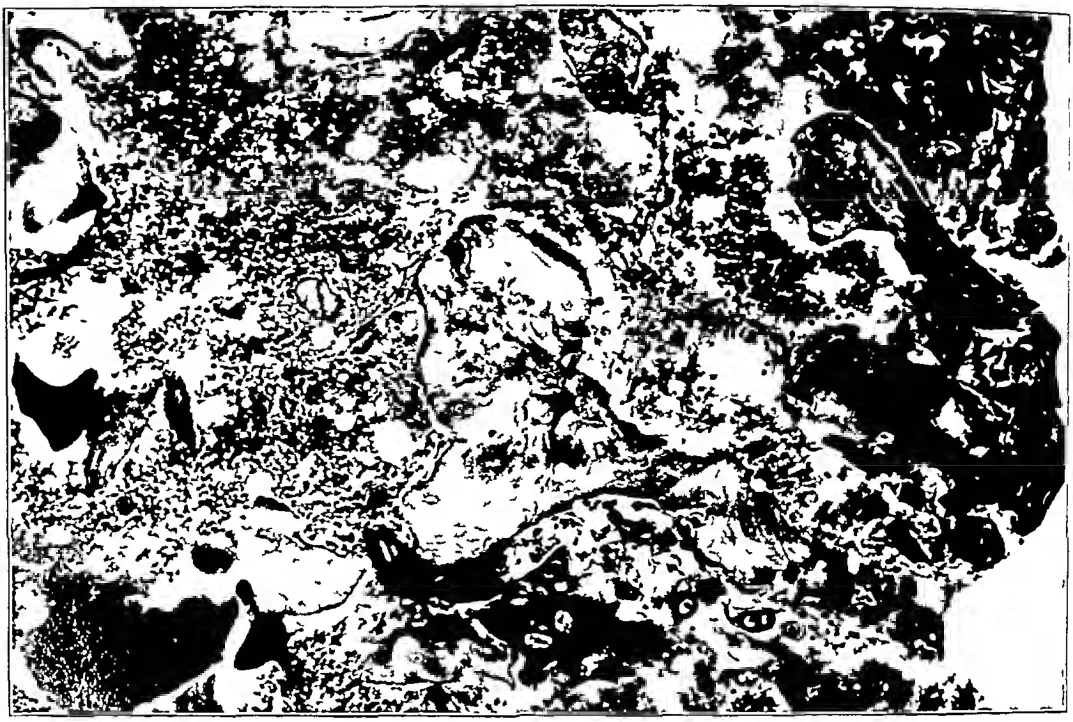

Fig. 4

Case 13. F. H., a white boy, aged seven years, had had symptoms for eleven months before operation. Clinical and roentgenographic diagnosis was Legg-Perthes disease. Pathologically, it was grouped with the degenerative and crushing lesions. The marrow spaces are filled with debris and displaced bony spicules. In the lower central areas and in the upper right portion, irregular ossification is taking place. (× 135)

1. *Degenerative Changes*

In every case, more or less degeneration, necrobiosis, or necrosis was present without any local evidence of the cause. The least destructive lesions involved the contents of the marrow spaces, and consisted of necrosis of the cells and stroma. There was constantly a diffusion of chromatin throughout the area, and the fatty stroma disappeared, together with normal marrow cells. In some such areas there was no evidence of repair, while in others the spaces were filled with a loose, watery-appearing fibrous tissue, infiltrated with a few lymphocytes and mononuclear cells. Some of the mononuclears were phagocyte for blood pigment and other debris. In some of the cases atrophic marrow with a few persistent marrow cells occupied spaces adjacent to the necrotic areas. Segmented leukocytes were uncommon, and in only two of the cases were they present in numbers sufficient to raise the question of concurrent infection. The absence of infection was supported by many negative cultures. In more advanced lesions, necrosis was extensive and complete, involving not only marrow, but cartilage and bony spicules from broken trabeculae. With necrosis as a basis, other changes to be described were superimposed.

2. *Crushing in Necrotic Areas*

In six cases, there was a pronounced appearance of crushing or jamming together of the degenerated elements, with too many different processes involved for the spaces they occupied. There was no gross evidence of crushing of the head in these cases, which made the finding hard to explain. As weight-bearing is generally accepted as a contributing cause and relief from it as sound treatment, it is probable that the femoral head is more resilient *in situ* than it appears, and permits the transmission of pressure to its content. Again, in some cases the process may be more active than in others and may actually show more changes per cubic millimeter. Finally, the crushing may not have existed in the head, but may have been caused by the pressure of the curette on unusually soft material.

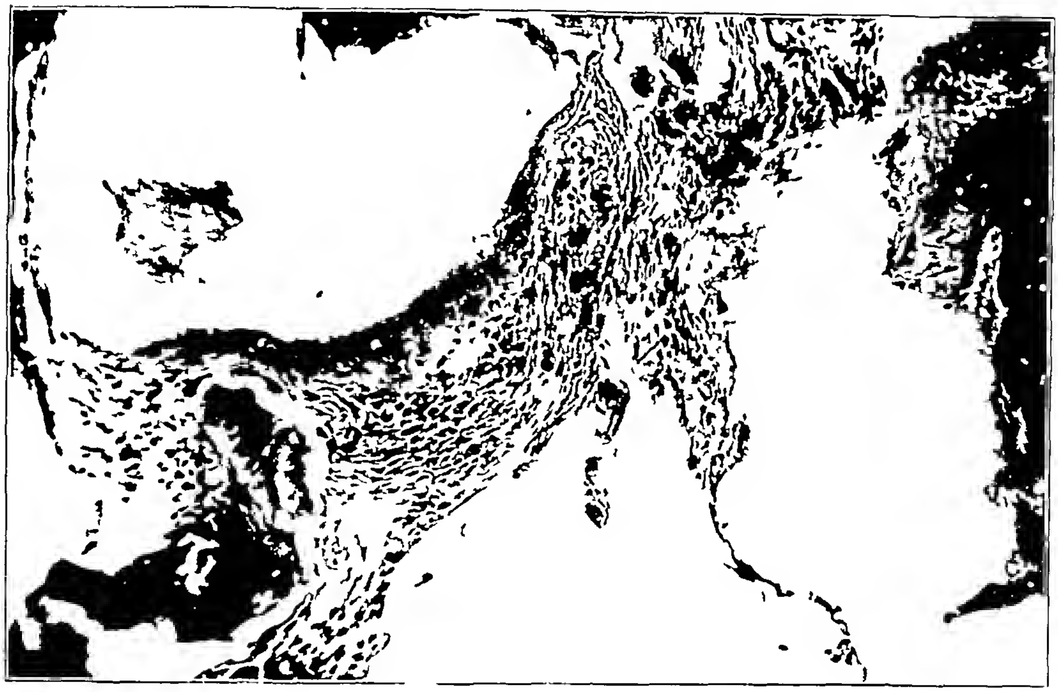

Fig 5-A

Case 10 E H, a white boy of eight years, had had symptoms for two years The clinical and roentgenographic diagnosis was Legg-Perthes disease Pathologically, this was grouped with the fibrocystic cases Other fields were typical of the disease A portion of three cysts is shown (× 135) The walls are fibrous and contain small giant cells

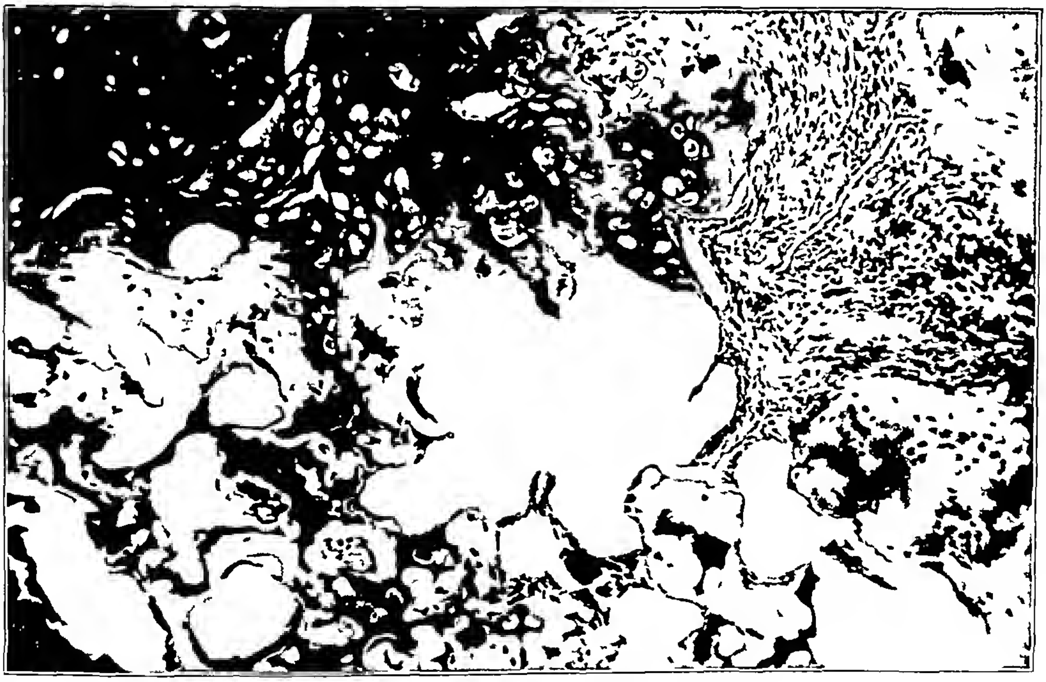

Fig 5-B

In the upper left corner, the polarity of the chondrocytes is disturbed and irregular ossification is present The dense type of fibrous replacement of marrow, regularly found in cases of Legg-Perthes disease with cysts, is seen in the upper right corner A cyst with fibrous and bony walls is found in the center, and bony-walled cysts, lined by a thin, fibrous layer, occupy the zone at the lower left (× 135)

The normal architecture was lost in these cases, and necrotic tissue was compressed between pieces of bone and osteoid tissue in a conglomerate mass Bits of cartilage, bone and granulation tissue were compressed into about half the space that such structures

would normally have occupied in unaltered bone The intratrabecular spaces were filled with homogeneous debris Irregular bits of displaced cartilage showed fragmentation with loss of nuclei, while others were undergoing ossification The cartilage in these areas apparently included bits from the operative door, the epiphyseal cartilage, and pieces of stray cartilage distributed indiscriminately throughout the head

3 *Reparative Processes*

Side by side with the degenerated areas, islets of healing were commonly found These varied from simple fibrous replacements of marrow, infiltrated sparsely with lymphocytes and occasional leukocytes, to dense bands of compact fibrous tissue All through the tissue which had been curetted, there were trabeculae of bone having unossified centers In some cases almost normal osteogenesis was present in one piece, while in neighboring bits there were fibrous cysts and heteromorphic osteoid tissue under formation

4 *Giant-Cell Reactions and Cystic Reactions*

Foreign-body giant-cell reactions occurred in twelve cases This does not mean that the giant cells were confined to osteoclasts around bony spicules, although they, too, were sometimes present Typical multinuclear foreign-body giant cells were collected about necrotic areas in several cases Lippmann mentioned giant cells as a part of the inflammatory reaction in his case In some of the cases thick, fibrous bands of connective tissue were present, which formed cysts, resembling a reaction of osteitis fibrosa cystica Giant cells might or might not be present in the cyst walls In one case, which was otherwise typical of Legg-Perthes disease, there was a giant-cell cyst resembling a benign giant cell tumor, and in another, a small osteoid osteoma, no larger than the head of a pin

5 *Changes in Cartilage*

As already mentioned, the loss of polarity of the cartilage cells was the outstanding cartilaginous change, and was present to a greater or lesser extent in all cases The chondrocytes were arranged in angular patterns, suggestive of constellations on the blue cartilaginous backgrounds Many pieces of cartilage were penetrated by arterioles with a border of mesothelial tissue about them Some of the spaces were filled with blood, in others the vessel was no longer present, but a small cystic space containing red cells persisted Such changes occurred in the cartilage from the operative door, epiphyseal cartilage, and stray bits of cartilage from incompletely ossified trabeculae, indiscriminately distributed throughout the femoral head

6 *Vascular Changes*

As a rule, there were no vessels in the degenerated areas Capillaries and thicker walled arterioles were present in the marrow spaces and were especially prominent in those filled with fibrous tissue There were no consistent vascular changes and no thrombi The presence of intermingled living and dead tissue seemed to argue against infarction as the cause of the necrosis

7 *Resemblance to Scurvy and Rickets*

Burrows mentioned two cases of bilateral Legg-Perthes disease, complicated by rickets Some of the lesions in our cases were suggestive of the changes seen in scurvy,—that is, there was no normal set pattern of ossification There was an excess of calcification in places, displaced osteoid tissue, and fibrous replacement of the marrow Some changes also resembled rickets in that there was no line of demarcation between bone and cartilage, there were displaced osteogenic patches, and numerous osteoblasts and osteoclasts were seen in the ossifying areas

Summary of Histological Changes

The presence of aseptic necrosis affecting marrow, cartilage, and bone, the fibroblastic changes, and the uneven lines of osteogenesis were consistent with the findings of

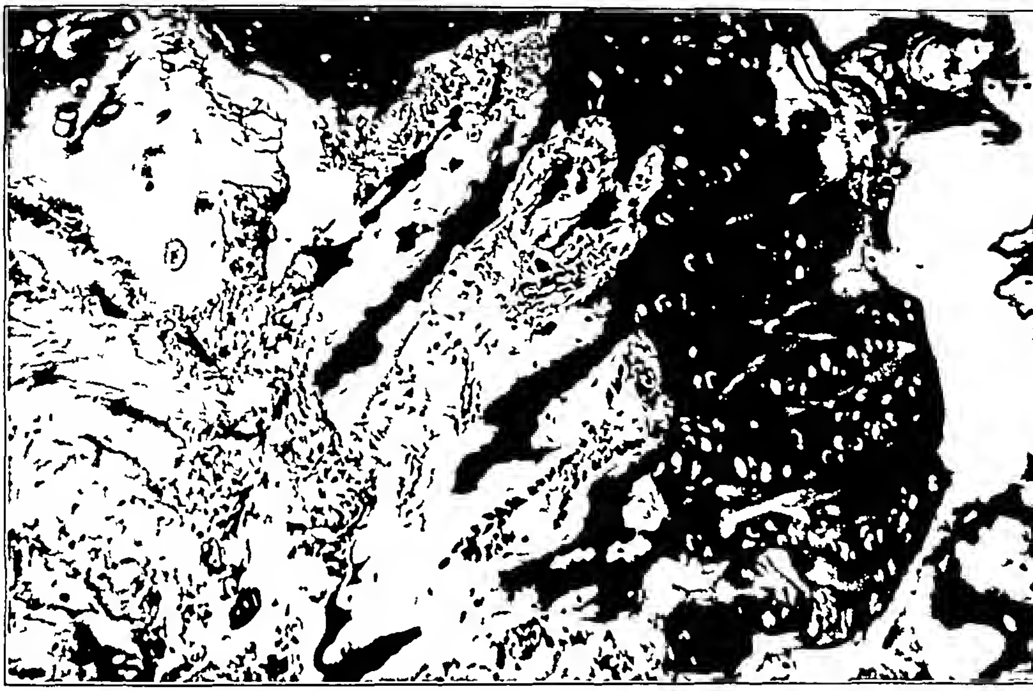

FIG 6-A

Case 31 E T, a white boy of seven years, had had symptoms for six months before operation Clinical and roentgenographic diagnosis was Legg-Perthes disease Pathologically, this case showed all of the changes characteristic of the disease and, in addition, a portion in which ossification was more or less orderly The chondrocytes at the right side are arranged in parallel columns and the osteoblasts appear normal, while the marrow spaces in the lower left corner are filled with necrotic tissue (× 90)

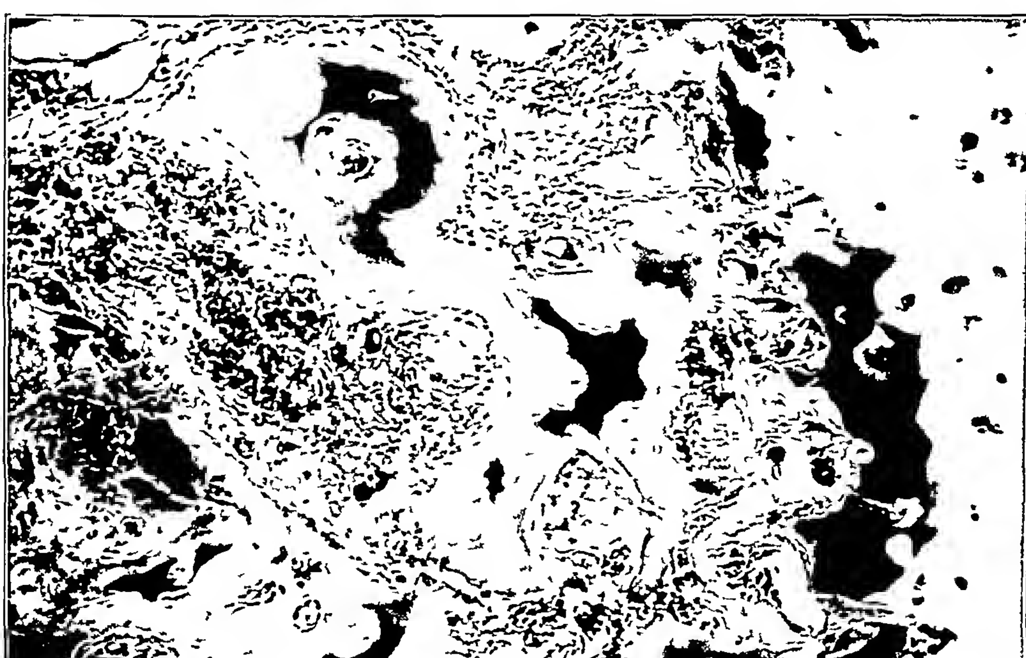

FIG 6-B

An area (× 90) showing almost all of the pathological changes of Legg-Perthes disease Note the resemblance to scurvy

Fig. 7

Case 16. G. H., a white boy, aged five years, had had symptoms for one year. Note the loss of polarity and distortion of chondrocytes in epiphyseal cartilage. Note cystic changes in the chondrocytes (× 120). The patient improved after operation, when given chorionic gonadotropin.

Zemansky, Gall and Bennett, Lippmann, and others. The general plan of the lesion w... similar for all cases, but the variation in degree of the respective changes was consi... erable. Giant-cell reactions have been mentioned in other papers, although the presen... of fibrous cysts, benign reactions like those of giant-cell tumor, loss of polarity of the chon... drocytes, and hemorrhagic cysts in the cartilage have not been emphasized. Attentio... has also been drawn to the resemblance of the changes both to scurvy and to rickets.

Relation of Age of Patient and Duration of Symptoms to Type of Histological Lesion

All of the cases were restudied to see if there was a consistent relationship betwee... the lesion, the duration of symptoms prior to operation, and the age of the patient.

Seven cases that were predominantly of the degenerative type occurred in childre... from four to ten years of age. The symptoms had been present from three weeks to eleve... months. Crushing or apparent collapse and moderate repair occurred in patients fro... seven to eleven years, with symptoms present from one week to twenty months. Case... which there was a predominance of reparative changes included patients whose age... varied from five to twelve years and whose symptoms had been present from five to eight... een months. The largest group, that with fibrous-cyst formation, included twelve case... seven in which the cyst walls had few or no giant cells, and five in which giant-cell c... were sufficiently prominent to suggest benign giant-cell tumors. As mentioned before, i... one case the reparative process stimulated a small osteoid osteoma. It was expected th... this group would be made up of older children with symptoms of several months' duratio... but it was not. For example, the most pronounced case of cystic change was in a bo... aged four, whose symptoms had been present for only two months. All of the children i... this group were between four and eight years of age, and their symptoms had been pre... from two to eighteen months. Save that all of the cases were prepuberal, it is obvio... from these data that no relationship was found between the age of the patient, the ons... of symptoms, and the type of lesion.

Histopathological Findings Bearing upon Hypotheses of Pathogenesis

The actual cause or causes of Legg-Perthes disease are not known, although many hypotheses have been advanced. The more common ones will be discussed in the light of the histopathological findings which tend to support some of them, throw doubt on some, and exclude others. The therapeutic agents mentioned in the discussion are not cited for the purpose of treatment but because they seem to give indirect evidence that endocrine disturbances are allied with pathogenesis.

Trauma is the most commonly cited pathogenic factor. Legg suggested trauma as the probable cause in thirty-seven clinical cases. Goldenberg reported five cases from the literature and one of his own in which Perthes' disease followed injury; one was a traumatic dislocation of the right hip followed by Perthes' disease. Many other authors have considered trauma the most important etiological factor. In seven of the author's cases there was a history of accident, but all of them were more or less trivial,—one child twisted a leg while swimming, one was kicked by another boy while playing, the most severe accident was a fall from a four-foot wall. In the other cases, the disease developed insidiously, so it seemed probable that the accidents were precipitating factors rather than actual causes. Microscopically, the only evidences of injury were possibly those of slow crushing and repair. In no case did the reparative changes suggest callus formation, either recent or late.

Among other conditions that have been suggested as causes of Legg-Perthes disease are acute infections, particularly those produced by *Streptococcus viridans* [15], tuberculosis, syphilis, and congenital anomalies. They could all be excluded in our series, because the lesions which characterize them were absent from the histological sections.

Several references in the literature indicate an association with vitamin and hormonal deficiencies and with other metabolic disturbances. Hyperparathyroidism has been suggested. Our cases with bone cyst-like changes resembled osteitis fibrosa cystica in a measure. Where blood-chemistry studies were made, both by Gill [8] and by the author, no consistent disturbance was found in the calcium-phosphorus-protein-phosphatase ratios. Moreover, the cysts were confined to the femoral heads and were usually solitary. In Gall and Bennett's case, there were disturbances in most of the blood-chemistry constituents. The patient was a boy who had long been known to have renal insufficiency, suggesting that factors other than Perthes' disease were responsible for the chemical disturbances.

Hypothyroidism has received more support than hyperthyroidism. Albright likened the changes in the hip joints to those occurring in cretins, and reported a case that improved under thyroid administration. Cavanaugh, Shelton, and Sutherland, and Schaefer and his associates found evidence of an association between Legg-Perthes disease and hypothyroidism. Cavanaugh, Shelton, and Sutherland reported five cases in which the patients improved after thyroid administration. Gill [8], after careful study of twenty cases, including blood-chemistry tests, basal-metabolic examinations, and roentgenographic plates for bone age, concluded that there was no evidence that the disease was due to hypothyroidism.

The bone age lagged behind the chronological age in all five cases of Cavanaugh, Shelton, and Sutherland. One showed the stigmata of sexual underdevelopment. Gill found the bone age less than the chronological age in some cases, and synchronous with it in others. Bone-age studies in the present series were done on those cases referred to our Research Department in Endocrinology and Metabolism.* Generally the bone age was behind the chronological age, but in one case the bone age was greater. Grauer considered this case to be a hypothalamic type, and the patient was treated with chorionic gonadotropin and with growth complex. Recovery was rapid without operation, and there was no opportunity to examine the contents of the femoral head.

* R. C. Grauer, M.D., Director of Research.

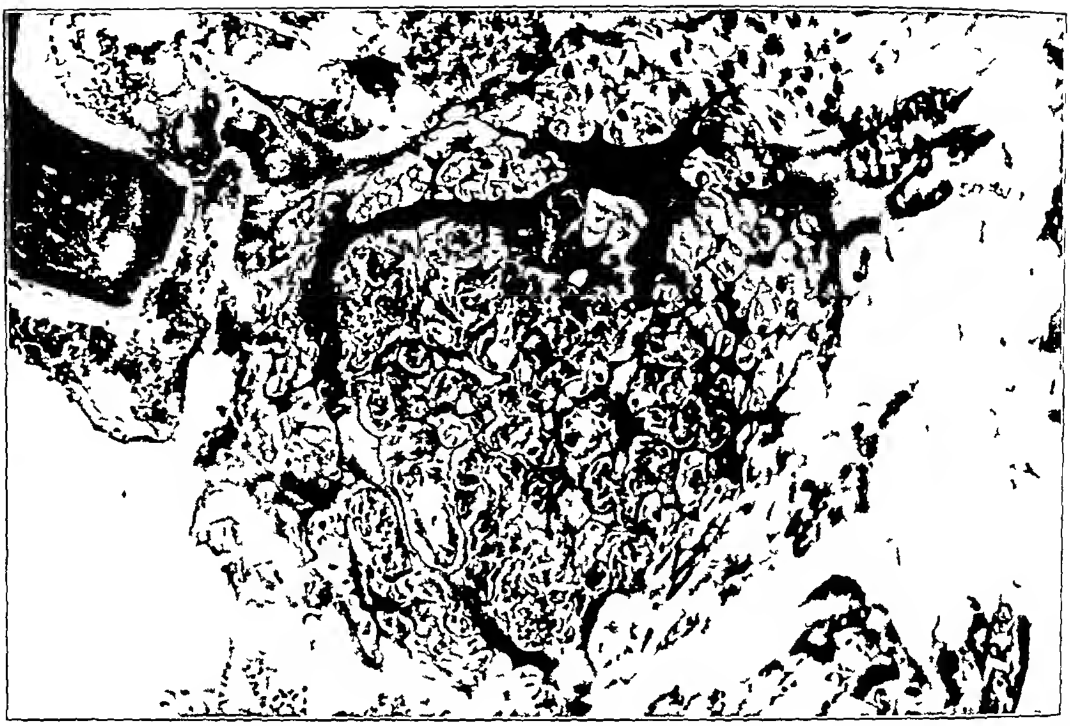

FIG 8

Case 24 J S, a white boy, aged eleven years, had had symptoms for seven months before operation The case was clinically, roentgenographically, and pathologically Legg-Perthes disease The photomicrograph (× 135) shows a small area resembling an osteoid osteoma The structure was smaller than the head of a pin

The cartilaginous changes in Case 16 were unusual

In G H, a white boy, aged five, who was obese, had a small penis, retractile testes, and other signs of sexual underdevelopment, healing was not so rapid as usual after the Steele operation The roentgenograms of the hip were typical The patient was referred to the Department of Endocrinology and was treated with chorionic gonadotropin, he made a gradual but complete recovery On restudy of the sections, it was found that the changes were typical of Legg-Perthes disease, except that the normal osteogenic pattern in the epiphyseal cartilage was absent It was replaced by a radial pattern with a central hub, made up of giant-sized cartilage cells lying in cystic spaces (Fig 7) Radiating from it were columns of cells which varied in size and staining reactions There was no bone formation in the nucleus, although there were bony trabeculae on each side of it

The case is cited for its probable relationship to sexual underdevelopment Grauer thinks that Legg-Perthes disease is not necessarily related to sexual deficiencies, but that several metabolic disturbances may be partially responsible and that each case should be studied individually

Brailsford, Ferguson and Howorth, Lippmann, and others believe that the necrosis is due to changes in the blood supply There were few vessels of appreciable size in the tissue curetted, there was nothing in our material either to confirm or deny the importance of such changes, and the ligamentum teres could not be examined

We examined tissue curetted from the femoral head in two cases diagnosed as osteochondritis coxae in patients between twenty and thirty years of age Both showed fibrous replacement of marrow and one had a small exostosis There was no irregular line of ossification or endochondral osteogenesis, and, in the absence of fracture, none should be expected, because union of the epiphysis and metaphysis is usually completed at the age of eighteen

CONCLUSIONS

1 The changes in the head and neck of the femur in children with Perthes' disease were constant within fairly narrow limits, and included aseptic necrosis or necrobiosis, evidence suggestive of crushing, concurrent degeneration and repair, partial ossification of displaced cartilaginous tissue, loss of polarity of chondrocytes, small cartilaginous

cysts, and areas of fibrous-cyst formation with giant cells in the walls, similar to those found in osteitis fibrosa cystica

2 The pathological changes are those of disturbed metabolism rather than of trauma or infection, and suggest that each case should be studied for bone age and disturbances due to hormone and vitamin deficiencies As no single deficiency seems to be present in all cases, each case should be studied individually

3 Removal of the contents of the head should in itself be beneficial, since it eliminates debris that may lead to the formation of cysts and giant-cell reactions

4 The interpretation of Legg-Calvé-Perthes disease, based on a study of the material presented, is (a) that the disease is primarily a prepuberal degenerative condition with aseptic necrosis of the epiphysis and upper portion of the metaphysis of the femur, depending in part upon some deficiency, (b) that the head becomes weakened to the point where weight-bearing injuries lead to slight flattening, and (c) that the remainder of the changes result from frustrated attempts at healing, which are obstructed by the presence of degenerated and displaced bone constituents and further complicated by the continued injuries of weight-bearing

NOTE The author's sincere thanks are acknowledged to Paul B Steele, M D , and J A Heberling, M D , of Allegheny General Hospital, for the privilege of reporting the pathological findings in their cases and for assistance in studying their records

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LOW INSERTION OF THE HIP NAIL*

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One of the common causes for failure in the internal fixation of fractures of the neck of the femur and of intertrochanteric fractures is that the metal cuts its way out of the head or neck. This is sometimes due to a marginal position of the nail or screw in the head[1, 2, 3, 4], and, particularly in intertrochanteric fractures, to a low insertion of the nail.

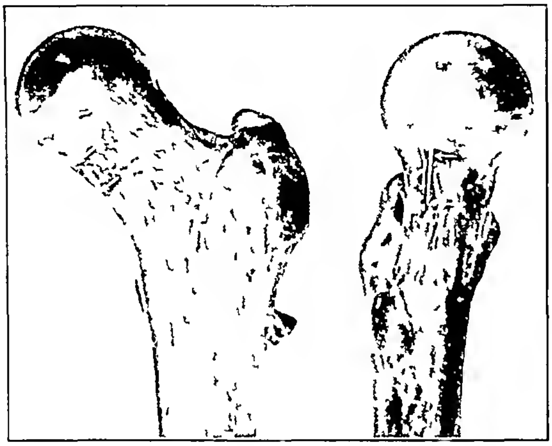

FIG. 1-A

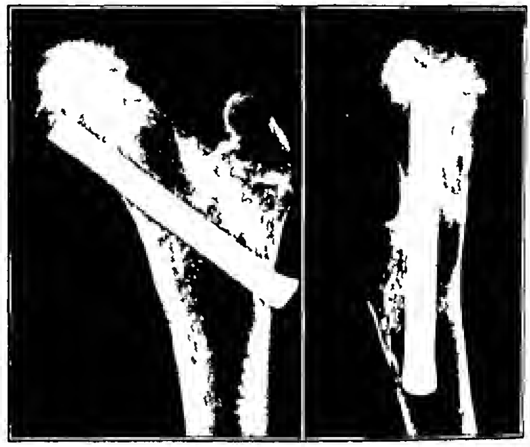

FIG. 1-B

Photographs and roentgenograms of the femur, illustrating too low insertion of the nail.

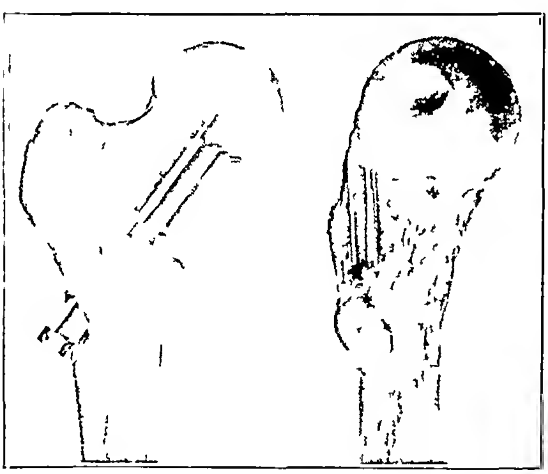

FIG. 2-A

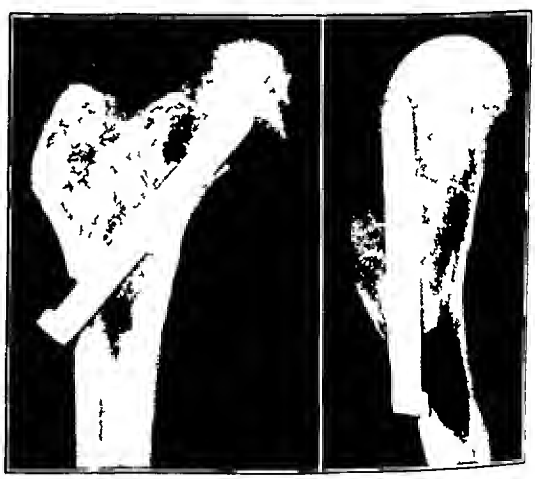

FIG. 2-B

Posterior and lateral views of low nail, placed posteriorly.

There is a lengthwise ridge of bone in the neck of the femur, in the roentgenographic shadow of which a badly placed nail or other device for internal fixation may give the deceptive appearance of being within the confines of the bone. In cross section, the neck of the femur has the shape of a teardrop. A nail inserted in the bulge of the teardrop is actually centrally placed and so appears in the anteroposterior roentgenogram. On the other hand, a nail which has been inserted too low in the neck may lie in part outside the

* Demonstrated as Scientific Exhibit, at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 22–27, 1949.

** Formerly Fellow in Orthopaedic Surgery, Northwestern University Medical Specialty Training Program.

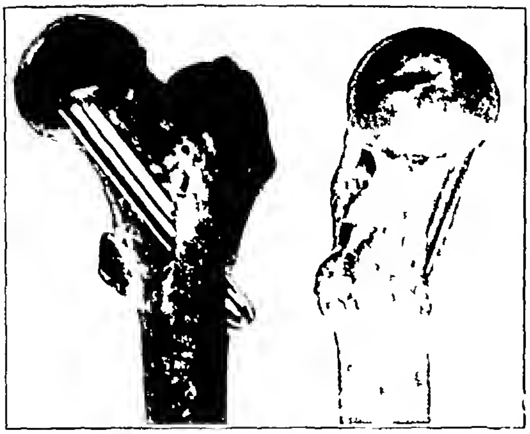

Fig 3-A

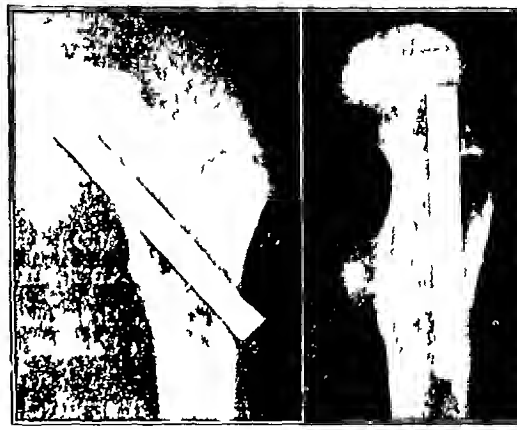

Fig 3-B

Fig 3-A Low nail, placed internally

Fig 3-B Although nail lies outside the neck, in the roentgenograms it has the appearance of lying within the neck

cortex, and yet give the roentgenographic appearance of being within the neck (Figs 1-A through 3-B)

Both roentgenographic projections must show the nails or screws to be centrally placed Maximum engagement in the bone of the head is obtained by the avoidance of marginal placement

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DISCUSSION

Fractures of the Tibia

(Continued from page 598)

situation risks joint injury, if not delayed function of that joint In certain cases I would have used skeletal traction and later a cast, and in other cases I would have done a simple closed reduction and applied a cast to the extremity with the expectation of good results In one case that Dr Naden showed, in which the patient had a rather marked oblique fracture of the lower end of the tibia with displacement, as well as a fracture through the upper end of the fibula, I would have done a simple internal fixation by using screws Such open operative technique is generally simpler than prolonged external pin fixation and produces, in my opinion, less potential infection than external pin fixation

The following remarks do not apply exclusively to the technique used in Dr Naden's cases However, in order to present a fault of internal pin fixation (one example being the intramedullary pin advocated by Kuntscher and others), I wish to say that the intramedullary peg was discarded years ago I refer particularly to the beef-bone peg used by Hendon and the cow-horn peg used by Fowler and others The objection to such intramedullary peg fixation was that it produced too much trauma to the vital bone-healing area at the fracture site, causing non-union in a large number of cases Too often such treatment requires a more radical surgical approach than does simple internal fixation A complicated fracture results, and more trauma is produced than by doing a simple open internal fixation Let's not be misled by a faddist treatment, but deal with each case as an individual problem, and apply the treatment to the fracture and not the fracture to the treatment

(Continued on page 618)

THE DISC SYNDROME

Results of the Conservative Care of Patients with Positive Myelograms

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Since Mixter and Barr first presented the concept of back pain and sciatica resulting from a displaced nucleus pulposus, this syndrome has been recognized with increasing frequency As with most scientific advances, the clarification of the pathological changes has raised a host of new problems, which are still partly unanswered The role of the herniated disc in the broad picture of backache and radicular pain is controversial Some clinicians believe that the disc accounts for a small fraction of such cases, while others believe that all back pain with radiation is encompassed within its limits Widely divergent views exist regarding operative indications, the extent of the operation to be done, and the question of whether or not spine fusion should follow disc removal

A start has been made on the clarification of some of these problems The results of disc surgery have been adequately reported in articles by Grant and his associates, Shinners and Hamby, and Lenhard Less has been reported, however, about what happens to those patients with clinical and myelographic evidence of a definite disc lesion, who have been treated conservatively Conservative treatment of proved ruptured intervertebral discs is not widely accepted A report of such a nature has been made by Kirstein In a review of the literature, no others were found It is the purpose of this paper to examine the results of this form of therapy

At the Hospital of the University of Pennsylvania, almost all of the cases of low-back pain and radicular pain are treated by a period of conservative therapy, consisting of bed rest on a firm support, traction, adequate sedation, daily physical therapy, and, when the patient is ambulatory, some form of back support If the patient fails to respond to these measures within a few weeks, and if there is a history of repeated attacks of severe pain, a myelogram is indicated If he is having an acute, intractable attack, and if there is definite myelographic evidence of a protruding mass, surgery is usually resorted to

The selection of patients for results on a non-operative basis poses a problem not encountered in the reporting of an operative series Employing only clinical means, can one beyond question select a patient having a ruptured or protruding nucleus pulposus? The authors believe this is not possible at present At this time myelographic studies, with pantopaque as the contrasting medium, offer the best confirmatory evidence of the presence or absence of protrusion of the dural contents or its roots Factors as yet incompletely investigated prevent a final, certain diagnosis from clinical findings alone Some of these are the role of the concealed or hidden disc, injury to the annulus, root adhesions, inflammatory changes of the nerve from adjacent arthritis, pressure changes in the foramen, and referred pain from ligamentous injury or postural strain,—all as yet to be completely unraveled

The group included in this study is small, but has been carefully reviewed Of twenty-eight patients studied, twenty-three were examined personally and the other five gave complete answers to a questionnaire In each patient a clinical diagnosis of protruded nucleus pulposus was advanced Such a diagnosis was usually based on a history of backache and radicular pain, associated with findings of impaired spinal mobility, spasm of the erector muscles, positive straight-leg-raising test, and sciatic scoliosis In addition, reflex

sensory changes and atrophy of the lower limb were commonplace. Routine roentgenograms of the lumbar spine and pelvis were either negative or showed some intervertebral narrowing. The patients were seen in consultation in the departments of Orthopaedic Surgery, Neurosurgery, and Neurology. Each patient was given an oil myelogram by members of the Radiology Department; a definite diagnosis of a protruding mass in the lumbar canal was noted under the fluoroscope and was confirmed by anteroposterior, oblique, and lateral views of the oil column. Patients with only air myelograms were excluded from this study because of the unreliability of this diagnostic medium. In a previous report[4], air and oil myelography was correlated with operative findings. This showed a high degree of accuracy for oil, but negative air studies could not be regarded as conclusive.

The twenty-eight patients in this study were followed from one to eight years after myelography, with an average follow-up of 2.7 years. Nineteen males and nine females comprised the group. The average age was thirty-nine; the oldest patient was sixty-seven and the youngest, seventeen years. All patients were treated with braces, restricted activity, and physical therapy following their hospitalization. Twenty lesions were in the fourth to fifth lumbar interspace, six in the fifth lumbar to first sacral interspace, and three in the third to fourth lumbar interspace. In one case the lesion was multiple.

The number of patients is small, as it is our practice to do myelograms only on patients who are to be operated upon. Thirteen patients improved remarkably with bed rest and traction. In four, surgery was withheld, as this was the initial attack. In seven others, the surgeon felt that the pain at the time of examination was insufficient to warrant operation. Four patients refused surgery. It may be pointed out that this group represents a cross section of patients more handicapped than would ordinarily be treated non-operatively, as surgery was anticipated in all.

RESULTS

The results in this series are viewed in relation to material from a prior study conducted in this Hospital[4], in which ninety-five patients were examined one to five years after removal of the lumbar intervertebral disc. In both of these investigations the patients were studied under the following groupings:

1. *Pain-Free*

This indicates that the patient is at present working, is completely free from symptoms, and that such an asymptomatic period is of more than one year's duration. Usually it indicates that the patient has been well since his hospital stay,—often considerably longer than a year. In spite of the absence of complaints, however, all of these patients cannot be considered to have normal backs; both those with and without surgery have been reluctant to engage in any strenuous activity, and they often demonstrate anxiety about future attacks.

In the non-operative group, eight patients (29 per cent.) were in the pain-free category; in the operative group, fifty-seven patients (60 per cent.).

2. *Residual Pain*

In this category are patients complaining of some residual or recurrent backache, either alone or in addition to radicular pain. The pain ranges from occasional mild disturbances to severe unremitting backache and radicular pain. Of the twenty patients in the non-operative group who complained of residual pain, fourteen had backache plus radicular pain, two suffered only radicular pain, and four complained of backache alone. Those patients in this category with marked disability are considered separately. Many were satisfied with their status. Twelve patients in this category (60 per cent.) suffered occasional pain; the remainder complained of constant pain. Such residual pain most often

TABLE I

RESULTS IN THE NON-OPERATIVE AND OPERATIVE SERIES

	Patients Free from Pain (No.)	(Per cent)	Patients with Residual Pain (No.)	(Per cent)	Patients Dissatisfied (No.)	(Per cent)
Non-operative	8	29	20	71	9	32
Operative	57	60	38	40	12	13

is precipitated by fatigue, overwork, or a specific act of heavy lifting or twisting of the spine.

In the non-operative group, twenty patients (71 per cent.) were in this category; in the operative group, thirty-eight patients (40 per cent.).

3. *Dissatisfied Patients*

Under this heading are those with residual pain who are subject to severe, recurring attacks of back pain and radicular pain. Some of these patients lose time from work each year; others are unable to work. In this category, the average period of disability since the onset of the pain has been over seven years.

In the non-operative group, nine patients (32 per cent.) are dissatisfied; in the operative group, twelve patients (13 per cent.).

In eleven cases followed three or more years with non-operative therapy, the results paralleled those of the entire group. Of the four patients in the total group of twenty-eight who refused surgery, two were dissatisfied, while the other two were pain-free under conservative care.

TABLE II

EFFECT ON OCCUPATION

	Patients Changing Work (No.)	(Per cent)	Number of Laborers	Laborers Changing Work (No.)	(Per cent)
Non-operative	12	43	13	10	77
Operative	19	20	48	15	31

OCCUPATION

Twelve patients in this study (43 per cent.) were forced to change their type of work. Of thirteen laborers, ten (77 per cent.) sought lighter work. In the operative series, nineteen patients (20 per cent.) changed their work and fifteen of forty-eight laborers (31 per cent.) shifted to lighter work.

THE MYELOGRAPHIC DEFECT

Each defect in the oil column was classified as mild, moderate, or severe, depending upon the degree of encroachment of the disc. If less than half of the column was indented, this was regarded as mild. A defect of more than half the column was called moderate, while any protrusion which divided the column was called severe. There were fourteen (50 per cent.) mild defects, nine (32 per cent.) moderate, and five (18 per cent.) severe. As far as we could estimate, the size of the defect in the spinal canal as viewed in the myelo-

gram showed no relation to the severity or persistence of symptoms, or to the clinical course of the patient. Three severe defects occurred in pain-free patients, and five of the nine dissatisfied patients had mild defects. These myelographic defects are not fully indicative of the true size of the disc, nor do they accurately locate the site of origin within the interspace. There is no reason to believe that the compression from the disc remains static. The occurrence of multiple acute attacks in many patients is oblique evidence that changes do occur.

CLINICAL FINDINGS

There are no definite features in the clinical examination which enabled us to prognosticate which patients would be relieved by conservative therapy and which would suffer repeated attacks. Patients complaining of pain at the time of follow-up examinations demonstrated some or all of the findings indicated. Those who were pain-free presented occasional atrophy as well as reflex and sensory changes. In 30 per cent. of this series the reflexes, which had been diminished or absent at the time of hospitalization, were fully regained.

DISCUSSION

Spine fusion combined with disc removal has been favorably reported by Barr. The combined operation resulted in a significant decrease of residual pain, both in the back and in the extremity. We know of no report in which spine fusion alone was performed on patients with clinical and myelographic evidence of disc protrusion, although we have the impression that, preceding popularity of the "disc syndrome", freedom from pain was achieved by the fusion operation in some cases of this type.

The diagnosis of herniated intervertebral disc is being made more frequently. It is commonly thought that this disease undergoes healing by natural processes in a large majority of non-operative cases. Conservative treatment is intended to assist such healing by minimizing those stresses that provoke symptoms. This study confirms our impression that, whenever the extruded mass has reached a stage where it can be visualized by myelogram, the prognosis under non-operative therapy is poor. Some of the patients now free from pain can expect further difficulties.

In this study, 57 per cent. of the patients have been intermittently disabled for five years or longer. If a reparative process occurs, it is time-consuming and robs the patient of many years in the productive span of life. Perhaps the more optimistic reports of conservative therapy are engendered by observation of an earlier stage in this syndrome. Perhaps, also, other conditions with a more favorable prognosis have been diagnosed as herniation of the disc.

Kirstein followed forty-nine cases of ruptured intervertebral discs. Each of his patients had a positive myelogram, but in only seven of these myelograms was oil employed, while oxygen was used in the remainder. The cases were followed from six months to three years. Twenty-five of the forty-nine patients were operated upon. Of the twenty-four treated conservatively, 12.5 per cent. were free from pain, 48 per cent. of the patients in his operative group were asymptomatic. In this study, 28 per cent. were pain-free. In a previous report from this institution[4], 60 per cent. of the patients operated upon were free from pain.

Dunning followed fifty-five patients having the older diagnosis of sciatic neuritis, and under conservative treatment. From the clinical records of these patients, he made a presumptive diagnosis of herniation of the disc. No myelograms were done. Thirty-six per cent. of his patients were pain-free and 18 per cent. suffered mild discomfort; 46 per cent. were classified as unsatisfactory. Dunning's series must have contained many cases in which the myelograms would have been negative, and this would make it doubtful that his total number of cases represented patients with herniation of the disc.

SUMMARY

1 Twenty-eight patients with the clinical diagnosis of displaced lumbar intervertebral disc, supported by oil myelography, were treated non-operatively and followed

2 Twenty-nine per cent remained pain-free for periods longer than a year, 39 per cent suffered insufficient residual pain to cause disability, 32 per cent were disabled by recurring attacks or constant pain

3 The results in this series compare unfavorably with the results obtained in a carefully selected operative series

4 The chronicity of this disease must be fully appreciated, most of these patients had suffered five years or more There can be little justification for letting the disease run its course

5 No evidence has been found by which the course of the condition may be forecast

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DISCUSSION

(*Continued from page 613*)

Osteomyelitis is an inevitable occurrence of the indiscriminate or indiscreet use of external pin fixation I use such technique in a few selected cases

Dr D C McKeever, Houston, Texas The remarks I wish to make concerning the use of external skeletal fixation are based upon experience with a method which I think is too frequently condemned without adequate trial While in the Service, I saw a large number of compound fractures of the long bones At one time, in a ward of 120 beds, all of the men had compound fracture of the femur In no case was the limb in traction or in plaster All patients except those with double compound fractures of the femur were walking with the aid of crutches In other wards in the same hospital other methods of treatment were used, and there was adequate opportunity for comparison

There is no question in my mind that the best initial treatment for compound fractures of the shafts of long bones is external skeletal fixation It cannot be used by everyone Before this method is attempted, one must have extensive knowledge of anatomy and mechanics, some degree of manual dexterity, and understanding of the principles involved in fracture treatment All open reductions and most closed fractures should have constant pressure bandages applied, in addition to the skeletal fixation I am not advocating this method in simple fractures, unless a large number must be treated quickly I believe that this method is the best one for handling quickly a large number of compound fractures of long bones Some form of apparatus for external skeletal fixation should be in the armamentarium of every orthopaedic surgeon The Stader and the Roger Anderson type of apparatus were compared in a large number of cases The Roger Anderson type is more adaptable to difficult cases and is much easier to use

OSTEOCHONDROMATOSIS *

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Osteochondromatosis is a condition in which cartilaginous and osteocartilaginous bodies are formed within and by the synovial membranes of joints and, occasionally, of bursae and tendon sheaths Synonyms include chondromatosis, synovial chondromata, joint chondromata, and diffuse enchondroma of the joint capsule

ETIOLOGY AND PATHOLOGY

Most authors believe that trauma contributes in some degree to the formation of these bodies The stimulus of a chronic inflammatory process, such as rheumatoid arthritis, has been suggested often Many believe that the origin is from embryonic rests of primitive cartilage The presence of cartilage has been demonstrated in normal synovial membranes The hypothesis of origin which has been most widely held in recent years is that of benign neoplasm, no evidences of metastasis or local infiltration being found Ewing's definition of tumor as "an autonomous new growth of tissue" is compatible with this hypothesis

Jones, in 1927, showed microscopically that the formation of these cartilaginous and osteocartilaginous bodies follows the same stages that occur in the embryonic formation of cartilage, as described by Keibel and Mall The cartilaginous bodies arise in the synovial membrane, directly from the fibroblasts (Fig 1) or from the lining cells, which are modified fibroblasts (Fig 2) The bodies usually arise in the stratum synoviale, rarely in the stratum subsynoviale As they grow, they usually become calcified and ossified, fat cells but no myeloid elements being seen between the spicules of bone Occasionally bone may form directly from fibroblasts (Fig 3) As the bodies increase in size, they may be forced to the surface to become pedunculated (Fig 4) When the pedicles break, as they frequently do, the bodies become avascular and the bone in them dies The cartilage cells near the surface live, nourished by the synovial fluid (Fig 5) The loose bodies are white, round or oval, with a smooth or faceted surface In number they vary from a few to hundreds

The synovial membrane in an involved joint may be thickened and villous The vascularity is increased, and focal collections of lymphocytes may be seen microscopically (Fig 6) Bodies which were previously free may become encysted in the membrane (Fig 5), and deep-lying bodies may be palpated

The process is apparently self-limited Fisher wrote in 1921 that the condition may cease "as suddenly and as mysteriously as it commences" Freund stated that there is often a gradual decline and even a disappearance of the joint bodies Faber and Bibergeil reported similar findings

One patient in the series reported here underwent two operations, one week apart, one with an anterior and the other with a posterior approach, for removal of more than 100 loose bodies of a hip joint, and there was evidence of the production by the synovial membrane of more Figure 7-A shows the preoperative roentgenogram The surgeon had been unable to remove all of the loose bodies (Fig 7-B), even with the second procedure

* Abridgment of thesis submitted by Dr Mussey to the faculty of the Graduate School of the University of Minnesota, in partial fulfillment of the requirements for the degree of Master of Science in Orthopaedic Surgery

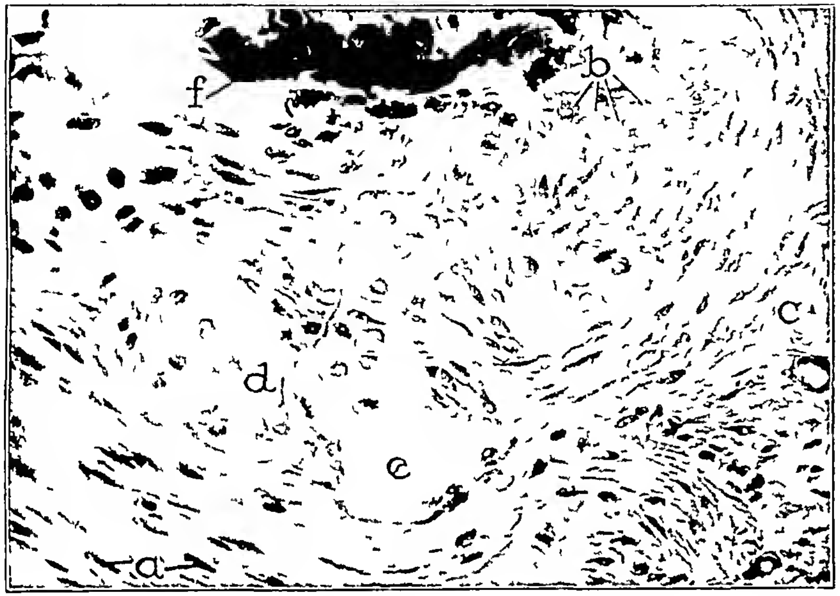

Fig 1

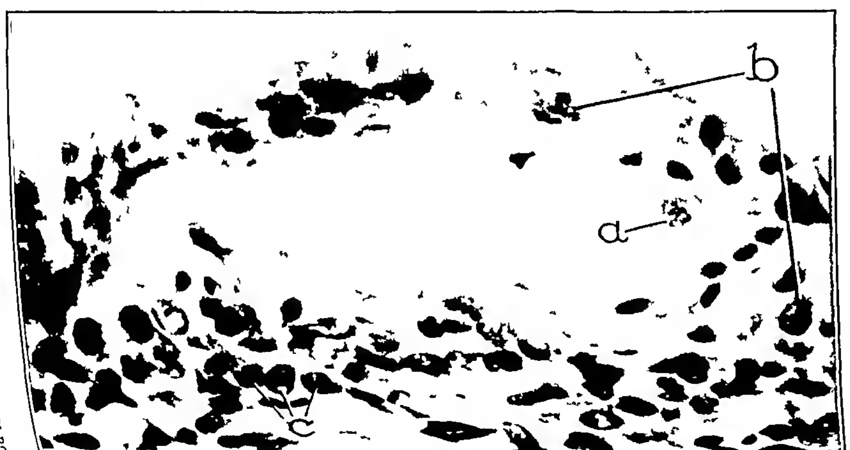

Fig 3

Fig 1 Fibrous-tissue cells (*a*) seem to be assuming a more rounded appearance (*b*) The matrix is becoming looser and more fibrillar (*c*) The cells become encysted in the matrix, which in some areas still retains a fibrillar structure, despite being partially hyaline (*d*) Some mature hyaline cartilage is seen (*e*) One area of calcified cartilage is present (*f*) (× 235)

Fig 2 This section (× 400), taken from the tip of an elongated, vascular villus, shows an area of cartilage surrounded by lining cells of the villus The encysted cell (*a*) and the cells becoming encysted (*b*) are indistinguishable from the lining cells (*c*) New cartilaginous matrix appears to be forming at both ends of the cartilage, in close conjunction with the lining cells

Fig 3 Stromal cells (*a*) enlarging (*b*) and forming bone directly, no cartilage being present Some of the cells (*c*) have become encysted in bon (× 200)

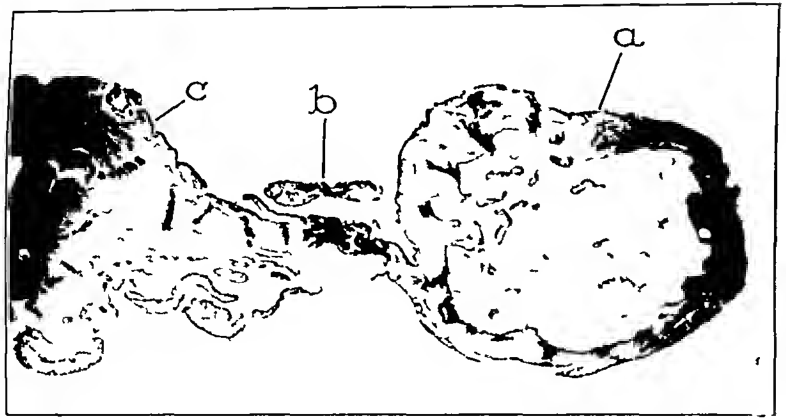

Fig 4

Fig 4 The osseous body (*a*) is connected by a pedicle (*b*) to the synovial membrane (*c*) (× 8)

Fig 5

Fig 5 This avascular body (× 15) is seen encysted in synovial membrane The only living cartilage cells are at the periphery of the body, the rest of the body is dead The dark areas are deposits of amorphous calcium

Fig 6

This very vascular synovial membrane (× 40) contains six cartilaginous bodies, one of them very small One (*a*) has thin connections with the large bone-containing body (*b*), which disappear in serial sections New cartilage is forming from fibrous tissue at *c* A focal collection of lymphocytes is present (*d*) The inner surface of the synovial membrane is particularly rich with blood vessels (*e*)

FIG. 7-A

Multiple calcified bodies may be seen around the hip joint before operation, along with spurring of the femoral head and narrowing of the joint space.

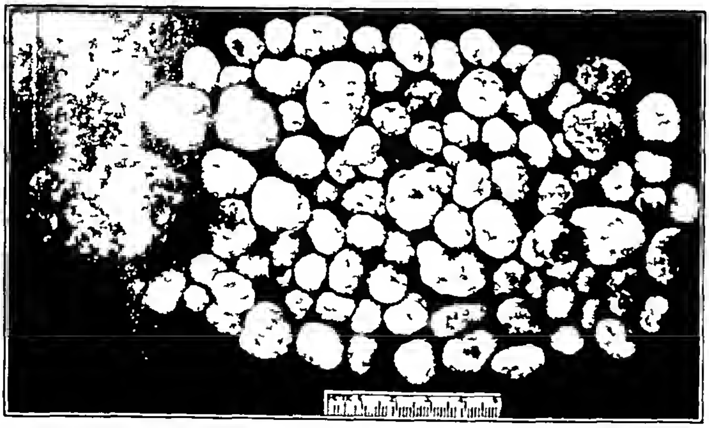

FIG. 7-B

Multiple loose bodies are seen, with a piece of the synovial membrane which contains calcified bodies.

(Fig. 7-C). Seven months later only one faint calcified area remained (Fig. 7-D). A shallow acetabulum and a misshapen femoral head were present. Since this patient did not obtain a satisfactory functional result more than four years later, a Vitallium-cup arthroplasty was performed for relief of pain and for improvement of motion. At that time only a very few small non-calcified, pedicled bodies were found.

Osteochondromatosis occurs more frequently in males than in females and is usually monarticular. The knee joint is involved most frequently, with the elbow second. Other joints affected more rarely are the hip, shoulder, wrist, ankle, temporomandibular, metacarpophalangeal, and interphalangeal. Bursae and tendon sheaths are seldom affected by this condition.

SYMPTOMS

The symptoms—weakness, aching, and progressive limitation of motion—are vague and chronic in type, and they vary according to the anatomical structure of the joint involved. Later, catching or locking may occur, although it is usually of a transitory

nature, followed by slight effusion, pain, and stiffness. There is rarely spontaneous pain, except with an episode of locking. A few patients mention that they can feel movable masses.

FINDINGS

Physical findings vary with the joint involved and with the degree of involvement. The joint may be normal to examination. Loose or fixed bodies may be felt. The joint capsule may be thickened somewhat, with moderate effusion. The motion of the joint may be decreased, although usually not markedly.

The roentgenographic picture varies with the stage of formation of the bodies and with their numbers. Calcification usually appears late and is generally not present in all of the bodies. Freund mentioned a patient who had an involved hip from which 395 radiolucent bodies were removed. If the condition has existed long, osteo-arthritic changes may be seen unless masked by the bodies.

DIFFERENTIAL DIAGNOSIS

In typical cases in which large numbers of bodies are demonstrable by roentgenogram or during surgical intervention, the diagnosis is obvious. Rice bodies (corpora oryzoidea), associated with chronic infections such as tuberculosis, are differentiated with ease microscopically and with relative ease on the basis of history and findings. When there are few bodies, the differential diagnosis may become difficult, because loose bodies may be pro-

FIG. 7-C

FIG. 7-D

Fig. 7-C. A few calcified bodies may be seen around the inferior aspect of the femoral neck in the post-operative roentgenogram. One is present above the superior spur on the femoral head. The presence of a shallow acetabulum and a deformed femoral head should be noted.

Fig. 7-D. Little residual calcification is present. That above the spur appears increased in density, owing to a different photographic technique. Actually the roentgenogram showed a slight decrease of density of the body.

TABLE I

Distribution of Affected Joints in 104 Patients

Joint Involved	Location			Total Number
	Right	Left	Bilateral	
Knee	36	30	7	73
Elbow	15	4	3	22
Hip	2	3	0	5
Ankle	1	1	0	2
Shoulder	1	1	0	2
Finger *	1	0	0	1
Totals	56	39	10	105 *

* Flexor-tendon sheath involved.
** In one patient, both an elbow and a knee were involved.

duced in osteo-arthritis, in osteochondritis dissecans, and occasionally after trauma. When the bodies are not radiopaque, the condition in the knee joint must be differentiated from a torn meniscus. The symptoms following a tear of the meniscus are more severe, particularly early in the condition.

Fisher, Smith, and Colonna all have written that a single body may be produced in osteochondromatosis. This is difficult to prove, for loose bodies of traumatic origin can become attached secondarily, as shown experimentally by Bloodgood, by Faber, and by Ito. Microscopic demonstration of a vascular body attached by a vascular pedicle should be sufficient to establish the presence of true osteochondromatosis (Fig. 4). In many cases definite proof of diagnosis will not be present because the process in the synovial membrane may disappear completely, leaving one or more bodies and a normal membrane. However, a careful history and physical examination will clarify the diagnosis in a great number of cases.

TREATMENT

Unless otherwise contra-indicated, all accessible loose bodies should be removed from any affected joint, because of the mechanical articular damage they cause. In addition, synovectomy should be performed when the synovial membrane is seen to be producing more bodies. Only in the knee is it practicable to remove a large proportion of the synovial membrane, and even in this joint the posterior areas do not lend themselves to removal. It must be remembered that calcified bodies, easily seen on roentgenographic examination, may be found not to be within the joint at the time of surgical intervention because they are either in bursae, have not yet been liberated from the synovial membrane, or are encysted in pockets of synovial membrane within the capsule. The involved bursae, together with the bodies, should be removed.

RESULTS

Osteochondromatosis will not recur if the process has reached an end at the time of operation. If all loose bodies have been removed after the process is completed and before any secondary osteo-arthritis has become manifest, the result should be excellent. However, traumatic osteo-arthritis from the presence of the bodies is frequently present before the operation, and this will militate against a perfect result. Nevertheless, surgical intervention is indicated in these patients to stop further articular damage.

The end results relative to few patients can be found in the literature. Wilmoth reported postoperative examinations in seven of nine patients operated upon. In three the

TABLE II

Results by Grades in Seventy-nine Joints, According to Age of Patient

Age at Operation (Years)	Number of Patients Followed	Grade of Joint			
		0	1	2	3
13 to 19	3		2	1	
20 to 29	16	1	2	7	8
30 to 39	10		4	3	5
40 to 49	13		4	8	3
50 to 59	23	2	4	4	13
60 to 69	7		4	2	1
70 to 76	1			1	
Totals	73	3	20	26	30

was no recurrence, in three the loose bodies remaining after operation were unchanged, and in one case the condition was essentially unimproved No patient was traced more than four years after operation

CLINICAL STUDY

The clinical records of all patients who had undergone operation at the Mayo Clinic from 1910 through 1945 for loose bodies in the joints or adjacent bursae were reviewed All cases were included in the present study in which four or more loose bodies had been removed, unless these bodies were apparently secondary to trauma Those patients from whose joints three or fewer bodies were taken were included only if there was a long history of disability, no definite trauma, and no hypertrophic changes roentgenographically, or if the synovial membrane, as seen during operation, appeared to be forming cartilage in any area

One hundred and four patients were included in this study Of these, twenty had been reported previously by Henderson and Jones or by Jones [10, 11] Seventy-nine, or about three-fourths, were males The average age at the time of their first operation at the Clinic was 42 9 years, eighty-eight patients being between the ages of twenty and fifty-nine years The duration of symptoms, in the ninety-five cases in which this was recorded, averaged 8 3 years The knee joint was chiefly involved (Table I)

Trauma was related by about half of the patients One-half of the patients with affected elbows and one-third of those with affected knees recalled trauma Five patients gave a history of an infection which might have been related to the condition Pain, catching, locking, and episodes of "going out of joint" were prominent symptoms, and some of the patients had noted swelling, loose bodies, or a mass Recurrent patellar dislocations had occurred in three cases Six patients had had previous surgical intervention for the removal of loose bodies Physical examination usually revealed decreased motion and, frequently, palpable loose bodies, masses, and enlargement of the joint

Besides demonstrating the calcified areas or bodies, roentgenograms showed osteoarthritic changes in half of the joints In six patients the corresponding contralateral joint was involved, although it was not operated upon

At the time of operation it was noted that some of the bodies were attached by pedicles to the synovial membrane in one-third of the joints, hypertrophic changes were seen frequently The synovial membrane occasionally appeared to be actively forming cartilaginous masses Loose bodies were found in either true bursae or sacs, connected with the articular cavity, in twelve patients Tendon sheaths were involved in two patients,—a finger-flexor sheath in one and the distal semimembranosus sheath in the other

Partial synovectomy was performed on twelve articulations. Ulnar-nerve transfers were done for pressure symptoms in five elbows. Transfer of the patellar-tendon insertion was made in two knees. Arthrodesis was performed on two knees for marked destructive changes, and one extremity was amputated for an associated chondrosarcoma of the distal portion of the femur. One or two subsequent procedures were carried out on sixteen patients because of remaining or recurrent loose bodies, or ulnar neuritis. There were no postoperative infections or deaths.

In nine patients, an exostosis was noted in the affected joint. One of these patients also had fibroma of the thigh, and another concurrent carcinoma of the colon. A tenth patient, mentioned previously, had chondrosarcoma of the femur. One patient had definite and one possible osteochondritis dissecans in the involved joint. The hip joints of two patients presented shallow acetabula and flattened femoral heads.

Microscopic examination of the synovial membranes from eighteen joints revealed active formation of new bodies. Four of the eighteen had been reported previously by Jones [11].

Postoperative visits or written reports were obtained from seventy-three patients. The average follow-up period for these patients after the first surgical procedure was 8.? years, with variations between one and thirty-two years. No case was included with a follow-up of less than one year. Two patients had died from unrelated causes, and one had died from associated chondrosarcoma. None of the seventy-three patients had had an operation subsequent to his surgical treatment at the Clinic.

In evaluation of the status at last report, four grades were employed. Those patients who said that they were unimproved were graded as 0. Those who were improved, but who had symptoms of any considerable degree or had suffered from subsequent locking were placed in Grade 1. Grade 2 included those with minimal symptoms, such as mild pain after much use of the joint, mild limitation of motion, or discomfort with change of weather. Those in Grade 3 had essentially no symptoms. Those in Grades 0 and 1 were considered to have unsatisfactory functional results, and those in Grades 2 and 3 to have satisfactory functional results. The age distribution of the traced patients and the results by grades according to age are seen in Table II.

There was no correlation between the number of surgical procedures and the postoperative result. There was a tendency for a better result in those patients who were followed a longer time after operation. Only four of the seventy-three patients complained of joint locking after operation.

Postoperative roentgenograms showed that calcified masses were present in eighteen patients, either in the capsule or loose in the joint. Of the fourteen of these eighteen patients for whom follow-up data were obtained, nine had satisfactory results and five had unsatisfactory results.

COMMENT

The etiology of osteochondromatosis cannot be stated definitely. This study does not support the hypothesis of infection. If the definition which Ewing uses is accepted, we believe this process to be one of benign neoplasm. An interesting finding is the coexistence of another tumor, usually an exostosis, in ten (9.6 per cent) of the patients. This would suggest an individual tendency toward neoplasia.

The importance of trauma as a stimulus is, as always, debatable. Repeated slight traumata to a joint which transmits a great deal of force and which is relatively unprotected seem important. The distribution of affected joints tends to support this conclusion, for 70 per cent were knees and 22 per cent were elbows. Of the elbows, more than two-thirds were on the right. In addition, three-fourths of all the patients were male. The traumatic episode related by the patient probably served only to focus attention to that joint and thus allow establishment of the diagnosis.

The patient who had definite postoperative disappearance of calcification, with later surgical confirmation of the disappearance of the actual bodies, confirms the roentgenographic findings of Bibergeil, of Faber, and of Freund. This phenomenon was seen in only one of the 104 patients.

CONCLUSIONS

1. Osteochondromatosis is a benign condition, probably neoplastic, involving the synovial membranes of joints, bursae, and tendon sheaths, in which cartilage develops by metaplasia of the connective-tissue cells of the membrane.
2. Repeated slight trauma may well be an etiological factor, although infection probably is not.
3. There may be an individual predisposition toward neoplasia.
4. All accessible loose or pedunculated bodies should be removed surgically, because of the discomfort to the patient and the danger of secondary osteo-arthritis, which is a frequent complication.
5. If the process in a knee joint appears active in the synovial membrane at the time of operation, synovectomy should be done.
6. Unsatisfactory postoperative results are usually due to osteo-arthritic changes in joint-surface contours, and not to loose bodies.
7. Spontaneous disappearance of loose bodies may occur.
8. Negative findings on microscopic examination of the synovial membrane do not necessarily negate a diagnosis of osteochondromatosis, for the process may have completed its cycle and the membrane resumed its normal appearance.

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VITALLIUM-CUP ARTHROPLASTY OF THE HIP JOINT

An End-Result Study *

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Since Smith-Petersen first reported in 1939 the method of Vitallium-cup arthroplasty for treating diseased hips, many orthopaedic surgeons have used this procedure, with varying results, and other studies have been performed [2 4 7] There is, however, a need to investigate completely and objectively the postoperative course of an unselected group of patients treated with Vitallium-cup arthroplasty A study has been made of all the patients with various pathological conditions of the hip who received cup arthroplasty in one clinic The purpose of this series is not to evaluate arthroplasty as a method of treatment, but rather to present an objective analysis of a group of cases in which it was used and to show the course followed and the results obtained It is hoped that this paper will stimulate other clinics or individuals to analyze and publish their results in like manner Only in this way will enough data be accumulated to forecast accurately the course of recovery of patients having Vitallium-cup arthroplasty of the hip joint

MATERIAL

At the New York Orthopaedic Dispensary and Hospital, forty-five cup arthroplastic have been performed on thirty-eight patients Twenty right hips and twenty-five left hip were operated upon, seven patients had bilateral cup arthroplasty Of the total number, twenty-nine patients (76 per cent) had disease in both hips and nine (24 per cent), in only one There were twenty-six females and twelve males The average age of all patient was 36 1 years, the average age of the females was 33 1 years and that of the males wa 42 7 years The youngest patient in the group was a six-year-old girl with congenital di location of the hip, but this case was not included in the average, as the age was so far out of line that it would have created a false average

The group is not great, either in total or in the number of individual pathological conditions, but it represents the entire number of operations

METHOD

The records of the patients were analyzed carefully and the pertinent information was recorded on a master chart, from this, the progress was followed Range of motion symptoms, and general functional results were recorded directly from hospital chart and no deductions were made To complete the study, the patients were recently interviewed and examined by the authors, the variations of multiple examiners thus being reduced to a minimum The serial roentgenograms were reviewed and, when indicated, new films were obtained In only 26 per cent of the cases were the authors unable to evaluate the present condition of the patient In these instances, the last clinical note closed the study

Evaluation Criteria

The chief indications for surgery were pain and marked limitation of motion In 70 per cent of the cases, both hips presented some limitation of motion

For purposes of analysis, it must be assumed that the operative technique was essentially the same, all operations were performed in the same Clinic, although by several different surgeons

The postoperative treatment was well standardized and consisted of

* Presented at the Section on Orthopaedic Surgery, American Medical Association, Chicago, Illinois, June 24, 1948

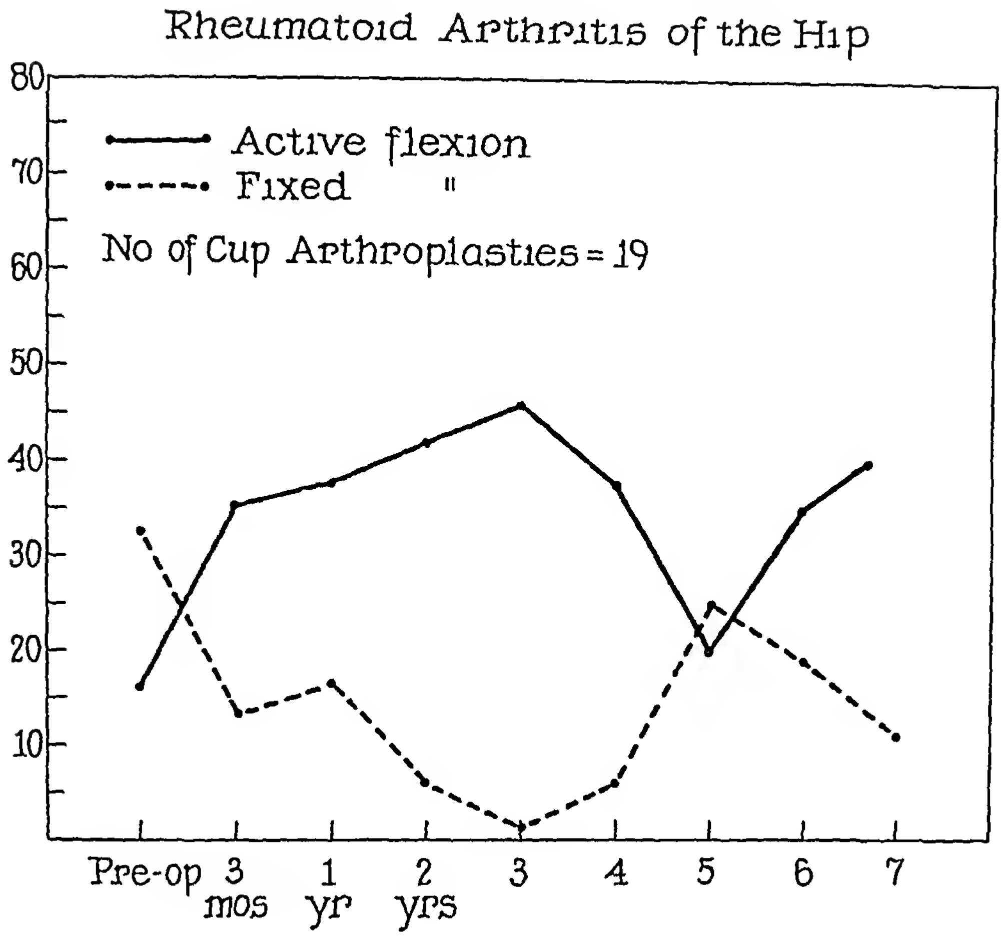

CHART 1

1. Traction-suspension for three weeks,
2. Roller-skating and active motion in a Hubbard tank, beginning at three weeks,
3. Use of a walker after three months,
4. Use of crutches after five months

At a personal interview, the patient's evaluation of the amount of pain preoperatively and during each succeeding postoperative year was obtained. This was checked against the clinical record. To further evaluate the symptoms, the distance the patient could walk (with pain as the limiting factor) in the preoperative and postoperative periods was ascertained. The range of motion was measured in accordance with the standards described by Cave and Roberts. This is recorded in positive figures, which means that a hip with motion from 90 to 160 degrees has 70 degrees of active flexion, 20 degrees of fixed flexion, and obviously no extension.

The roentgenograms were evaluated in accordance with the criteria stated by Smith-Petersen [6] in his instructional course on arthroplasty of the hip.

End-Result Evaluation

A true evaluation of the results from this type of operation can be made only in relation to each individual case. No arbitrary standard can rightly be applied to all. Therefore, the evaluating standards used in this paper must be explained. The cases are classified as "very good", "good", "fair", or "poor" after having been analyzed according to

1. *Motion*. The best case in the series, a patient with a five-year follow-up, had 5 degrees of fixed flexion, 95 degrees of active flexion, 30 degrees of abduction, 45 degrees of adduction, and 5 degrees of both internal and external rotation. This totals 180 degrees of active motion. This case formed the basis of criteria for evaluating motion.

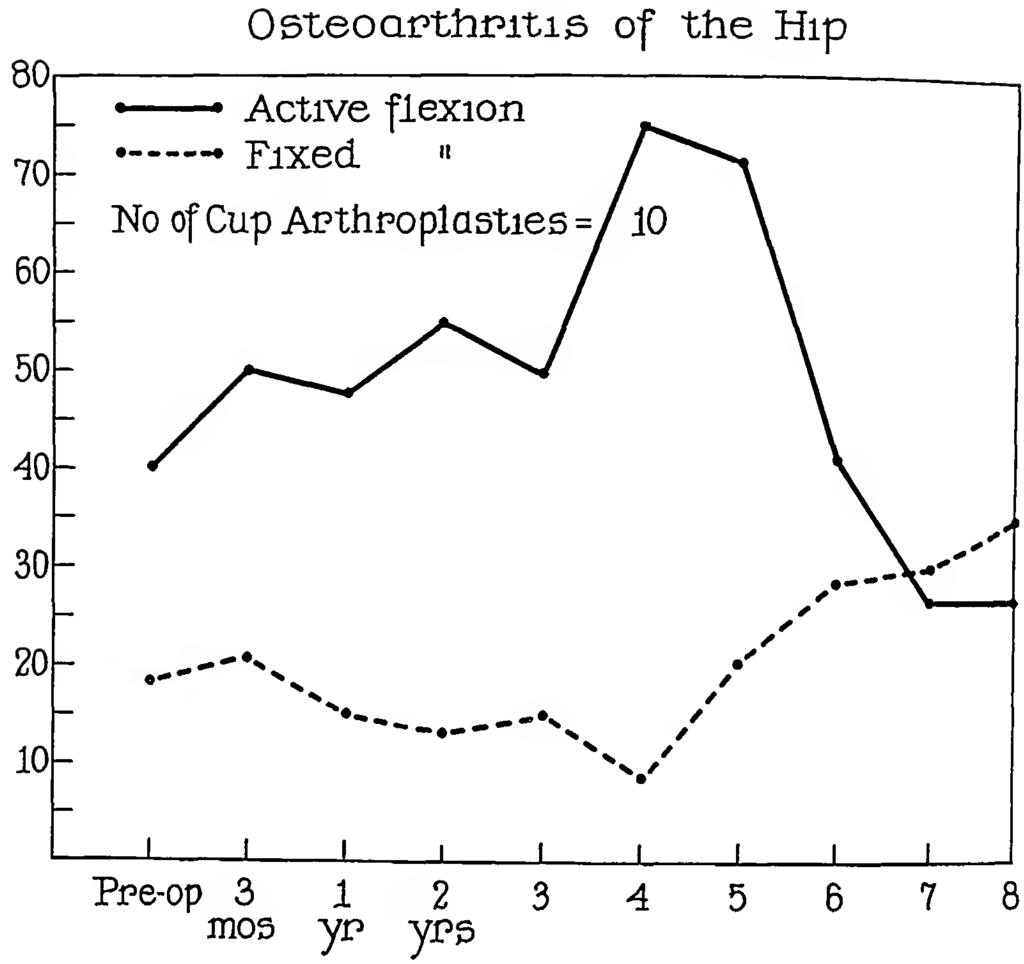

CHART 2

2 *Pain* In this series, a good result means no pain at any time

3 *Economic Status* The patient's preoperative occupation was the basis upon which his postoperative result was judged

ETIOLOGY

The cases fell into eight etiological groups, including rheumatoid arthritis, osteoarthritis, congenital dislocation, post-infection arthroplasty, slipped femoral epiphysis, arthrokatadysis, arthritis secondary to trauma, and osteochondritis dissecans In analyzing these groups as to symptoms and physical findings, figures on range of motion were tabulated at preoperative observation, within three months after operation, and yearly thereafter Although all patients did not continue to report regularly, the follow-up figures extend from one to eight years—from the first case done in May 1940, to the last in September 1947—the average being 3 22 years

Charts 1, 2, and 3 indicate the average range of motion in different etiological groups For purposes of clarity, only the degrees of active flexion and of fixed flexion were plotted The other hip motions were in proportion to the active flexion

Each case has been analyzed carefully Time and space will not permit their illustration and evaluation individually, so they are being discussed here by etiological group

Rheumatoid Arthritis

In sixteen cases of rheumatoid arthritis, Vitallium-cup arthroplasty was performed because of pain and limitation of motion of the hips The average age in this group was 33 5 years The known duration of the disease prior to surgery was 7 5 years, and the duration of pain in the affected hip was 3 7 years Table I is a typical example of the factual data assembled from these cases It will be seen from Chart 1 that in general

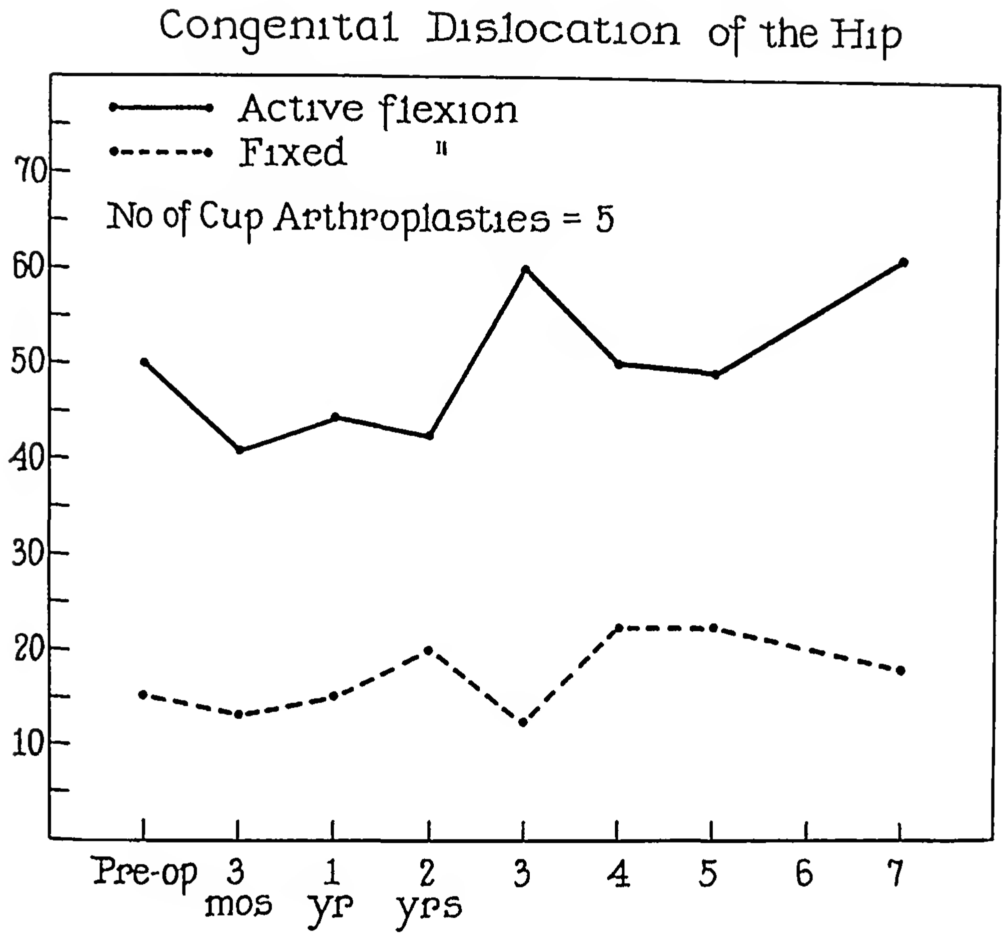

CHART 3

the hip motions, especially active flexion, continued to improve through the third year, after which the degree of motion gradually declined

Twenty arthroplasties were done for rheumatoid arthritis In one case the patient died six months after operation The end results of the other nineteen were tabulated (Table II) Although these ratings were made primarily from the surgeon's standpoint, most of the patients were satisfied with their results In general, a greater number received relief from pain than obtained good hip motion Figures 1-A and 1-B show preoperative and postoperative roentgenograms of a case having a poor result Figures 2-A and 2-B are similar views of hips showing a good result, the postoperative roentgenogram was taken seven years after the arthroplasty

TABLE I

DEGREE OF MOTION BEFORE AND AFTER ARTHROPLASTY IN CASES OF RHEUMATOID ARTHRITIS

	Fixed Flexion	Active Flexion	Extension	Abduction	Adduction	Internal Rotation	External Rotation	No of Hips
Before operation	32.5	16.2	0	5.2	2.9	1.9	2.5	20
After operation								
3 months	12.8	36.2	0	20.1	8.8	4.0	3.2	20
1 year	16.0	38.0	0	16.5	13.1	4.2	8.0	18
2 years	6.0	42.1	0	13.6	16.0	6.0	13.3	10
3 years	1.0	47.0	0	15.0	18.0	2.0	12.0	7
4 years	6.0	39.0	0	16.0	15.0	7.5	3.5	7
5 years	25.0	21.6	0	6.6	15.0	1.6	13.3	5
6 years	16.6	35.0	0	15.0	21.6	0	0	5
7 years	11.6	41.6	0	5.0	25.0	15.0	3.3	5

TABLE II

RESULTS IN NINETEEN ARTHROPLASTIES * FOR RHEUMATOID ARTHRITIS

	Number of Cases
Motion	
Very good (180 to 115 degrees)	2
Good (115 to 80 degrees)	3
Fair (80 to 50 degrees)	8
Poor (50 to 0 degrees)	6
Pain	
None	8
Minimal	3
Moderate	6
Severe	2
Economic status	
Same job (no limitation of activity)	3
Same job (limited activity)	2
Sedentary occupation	6
No job	4

* Twenty arthroplasties were performed, one patient died six months after operation

In three arthroplasties in this group, revision was required because of decreased motion and increased pain In one case, trauma to the hip, two years after operation caused a draining sinus of the wound The cup was removed in this instance

Osteo-Arthritis

Of nine patients upon whom ten cup arthroplasties were performed for osteo-arthritis, the average age was fifty-seven, the average known duration of the disease was 12 5 years, and the average duration of pain was 5 9 years The indications for operation in cases of osteo-arthritis usually were pain, involvement of both hips, which contra-indicate arthrodesis, and stiffness in the lumbar spine

In general, after surgery the motion increased until the fourth year and then declined somewhat (Chart 2) At that point the degree of fixed flexion deformity was the least

TABLE III

END RESULTS IN NINE CASES OF OSTEO-ARTHRITIS ‡

	Number of Cases
Motion	
Very good (180 to 115 degrees)	2
Good (115 to 80 degrees)	3
Fair (80 to 50 degrees)	1
Poor (50 to 0 degrees)	3
Pain	
None	1
Minimal	5
Moderate	2
Severe	1
Economic status	
Same job (no limitation of activity)	2
Same job (limited activity)	5
Sedentary occupation	1
No job	0

‡ Ten arthroplasties were performed, one patient died eight days after operation

TABLE IV

END RESULTS IN FIVE ARTHROPLASTIES OF THE HIP

	Number of Cases
Motion	
Very good (180 to 115 degrees)	2
Good (115 to 80 degrees)	1
Fair (80 to 50 degrees)	1
Poor (50 to 0 degrees)	1
Pain	
None	5
Minimal	0
Moderate	0
Severe	0
Economic status	
Same job (no limitation of activity)	3
Same job (limited activity)	0
Sedentary occupation	2
No job	0

These patients maintained their postoperative motion longer than any other group in this series, except for those with osteo-arthritis secondary to a slipped upper femoral epiphysis

All of the nine patients with osteo-arthritis stopped using crutches at the end of one year However, four of them, including one patient who had a bilateral arthroplasty, were using some form of support when last seen The one patient whose condition was followed for eight years had to resume the use of crutches at the end of seven years

The end results in this group are classified in Table III No relation was found between pain and motion or between motion and age One patient, aged sixty-five, died on the eighth postoperative day as a result of pulmonary embolism from phlebothrombosis of the lower extremity In one case in this group a revision of the arthroplasty was required, three months after operation, as it was feared that the cup would become dislocated

Congenital Dislocation

The average age of five patients with congenital dislocation of the hip was 23 9 years, the duration of symptoms was 14 4 years, and the average duration of pain was 1 8 years In this group the range of motion (Chart 3) continued to improve through the seventh postoperative year, although a slight degree of fixed flexion was still present

These patients were satisfied with their results, none of them required a cane or crutches at the end of one year At the end of two years, two patients required the use of a cane One of the two patients whose condition was followed for seven years could walk about three miles without discomfort and without the use of support Only one of the five patients required a cane at the time of a recent evaluation As in the other groups, there was no correlation between pain, motion, and age The classified end results are shown in Table IV

One patient had a revision of her arthroplasty at the end of five years, as motion had markedly decreased and the roentgenograms showed increased bone proliferation Another revision was required in a six-year-old child At the end of two years the cup was removed, because it was found that the other structures had grown out of proportion

Post-Infection Arthroplasty

Two patients having ankylosis of the hips due to previous infection were treated by cup arthroplasty, one case was bilateral The average age of these patients was 19 5

years, the known duration of disease averaged 11 5 years, and the average duration of pain was 1 5 months Although the group is small, the figures obtained show that motion was decreasing at the end of two years and that the amount of fixed flexion was increasing

The patient who had a bilateral cup arthroplasty was still using crutches at the end of two years, but required no support when last seen The other patient required neither

FIG 3-A
Bilateral slipping of the upper femoral epiphysis

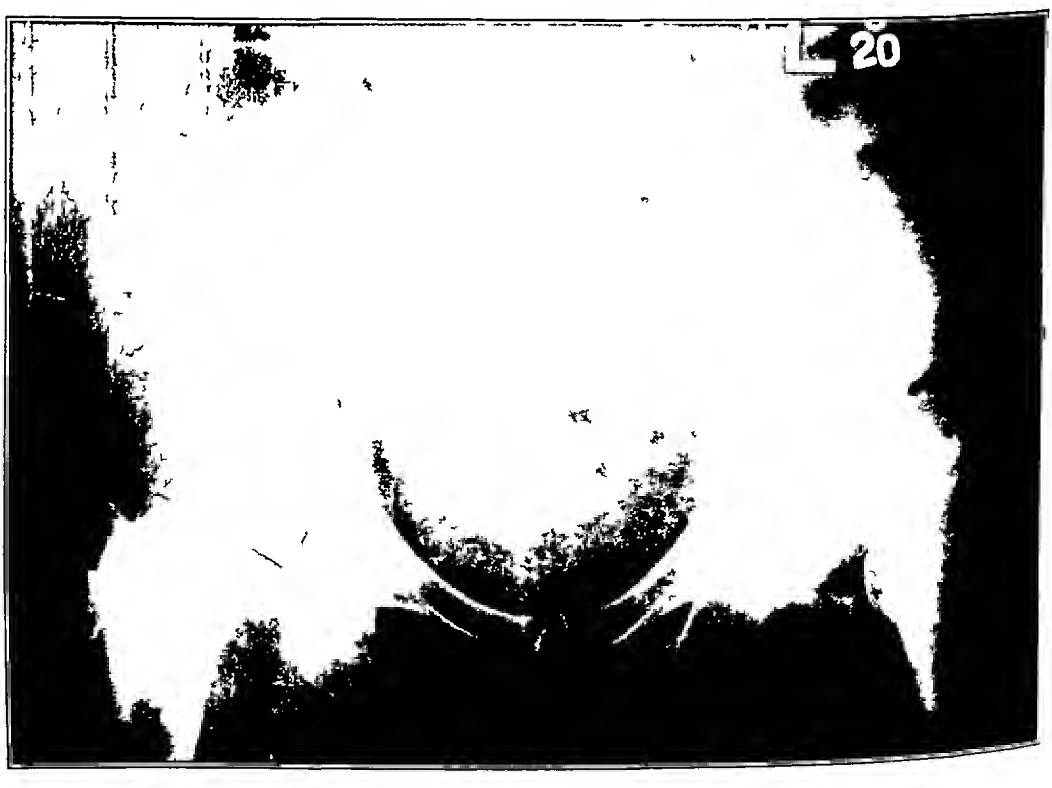

FIG 3-B
After cup arthroplasty, this patient had one of the best results in the entire series

came off crutches at the end of five years, but was using a cane at the time of a recent interview

The range of motion in these cases was poor, being below the total of 50 degrees Pain was absent in two of the hips and only moderate in the other Both patients returned to their previous sedentary work Although the range of motion is poor, the patients are definitely improved, both as regards the amount of pain and the ability to earn a living Revision was required in both of these cases, one at two months and the other at six months New cups were placed, in order to give less pain and to allow a greater range of motion

Slipped Femoral Epiphysis

Only two patients had cup arthroplasty for slipped femoral epiphysis Their average age was thirty-one years, the known duration of disease averaged 18 5 years, and the average duration of pain was 1 3 years The indications for surgery were pain and stiffness caused by osteo-arthritis, secondary to a slipped epiphysis Motion increased through the third year, after which a decrease was noted Neither patient required a cane or crutches after six months

The end results in both patients in this group can be considered good by most standards, as motion was very good and there was no pain Both returned to their previous occupations, one was a stenographer, the other a farmer Neither has pain or limitation of activity, and neither required any revision

A case of bilateral slipped femoral epiphysis (Fig 3-A) had one of the best results (Fig 3-B) in the entire series

Arthrokatadysis

The one patient having arthroplasty for arthrokatadysis was eighteen years of age, the abnormality had been present since birth She had fixed flexion deformity of both hips, but no pain

A bilateral arthroplasty was done Active flexion continued to improve, and the fixed flexion to decrease At the time of last examination, the patient had a minimal amount of pain, but only fair motion in both hips, she required the use of crutches at all times Her general condition has improved somewhat, but the result is not satisfactory to the patient

Arthritis Secondary to Trauma

Two patients had arthritis of the hip secondary to previous trauma Their average age was 27 5 years, the average known duration of disease was twenty-one years, and the average duration of pain was six years

Although the follow-up is very short, the range of motion is increasing while the fixed flexion deformity has decreased One patient had a very good result, he has an excellent range of motion without pain, and has returned to his duty as a farmer The other has improved, but still uses a cane He has a poor range of motion and is able to maintain only a sedentary job, pain is of moderate amount This patient's cup dislocated four days after operation, so that an open reduction was necessary

Osteochondritis Dissecans

The one case of osteochondritis dissecans occurred in a patient thirty-six years of age The known duration of the disease and of pain was six weeks An arthroplasty relieved the pain and allowed him an increasing amount of motion The patient, a chronic alcoholic, had irregular living habits which affected the end result, however, he did achieve a fair amount of activity with the use of a cane This patient was found in his room, dead of acute alcoholism, just four years after the operation

DISCUSSION

The results in these cases are not surprising, in view of the indications for which the operation was performed The majority of cup arthroplasties were done when the probability of arthrodesing the other hip was great With such a high percentage of bilateral hip involvement, age did not make much difference No patient died from the operation itself, although one death was due to a surgical complication, phlebothrombosis

None of the patients upon whom cup arthroplasty was performed later had hip arthrodesis Even a patient with a poor result from arthroplasty did not desire the arthrodesis In three cases with poor results, the patients felt that the operation had not been worth while

Although the most common indications for cup arthroplasty were pain and limitation of motion in the hip, the majority of the patients valued the relief from pain more than the motion

The gait of patients with good range of motion was smooth However, in all cases a limp was perceptible to the examiner The use of a cane or crutch in walking was required in 45 per cent of the cases Of the seven bilateral cup arthroplasties evaluated, one patient used no support, one used one crutch, and the rest used two crutches for ambulation

SUMMARY AND CONCLUSIONS

No definite conclusions can be drawn from a review of this number of cases, but the following impressions were received

1 No correlation was found between age, motion, pain, and sex

2 The results for the total group were not outstanding When, however, individual cases were considered in regard to indications and postoperative course, the results were quite satisfactory

3 Seventy per cent of the patients were relieved of pain

4 There is a definite period after operation during which the range of motion increases and the amount of fixed flexion deformity decreases This occurs, in general, between the second and third years

5 No patient in this series either had arthrodesis or wished to have it performed because of a poor arthroplasty result

6 The best results occurred in patients having slipped femoral epiphysis The poorest results were in patients with previous infection of the hip

7 A series of cases of hip arthrodesis is being studied in exactly the same manner From these two studies, definite conclusions as to indications and contra-indications will be drawn

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AMPUTATIONS FOR FAILURE IN RECONSTRUCTIVE SURGERY*

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At Walter Reed General Hospital, one of the Army Amputation Centers, approximately 600 amputations were performed between October 1945 and October 1947. In this paper are discussed 250 in which numerous phases of reconstructive surgery had been performed during the preceding five years. In the remaining 350 cases not reported in this paper, the amputations were performed for reasons other than failure in reconstructive surgery,—such as for the treatment of primary vascular injuries and diabetic gangrene, incomplete traumatic severence, or malignant tumor.

The most apparent reason for this large number of reconstructive failures is that Walter Reed General Hospital is one of the last remaining Army Amputation Centers. The patients were transferred from other General Hospitals and from other services in this Hospital, when amputation was considered advisable.

The average period of reconstructive treatment from time of injury to amputation was well over two years, compared to an average of five and one-half months necessary for rehabilitation after amputation. The range was from four to sixty-eight months for reconstructive treatment, and from two to twenty-nine months for rehabilitation after amputation. The average age in this group of 250 patients was twenty-three years, few being outside the range of seventeen to thirty-five years. Two hundred and forty-six (98.4 per cent.) of the amputations were of the lower extremity. The authors realize that the youth of this group, and the fact that the majority were lower-extremity amputees, aided greatly in obtaining favorable rehabilitation.

In spite of the advance and the improved techniques developed since the beginning of the First World War in plastic, orthopaedic, vascular, neural, and allied reconstructive surgery, surgeons doing this work should not lose sight of the proposed functional result or ignore the time necessary for the reconstruction. Since World War II, published articles have cited remarkable feats in reconstructive surgery, performed in military and civilian hospitals. The authors of these articles have sometimes neglected to show clearly the ultimate course in the cases which were functional failures,—those which finally came to amputation. The entire group reported here constitutes those seldom-mentioned failures.

Watson-Jones stated: "Amputation is seldom necessary in the treatment of bone and joint injuries, and the decision to adopt this unusual and drastic measure should always be supported by a second opinion. If the main blood vessels are not destroyed and there is no irrecoverable nerve lesion, the limb should be saved no matter how severe the contamination of a wound, the comminution of a fracture or the destruction of skin." The authors agree that the primary aim in the initial treatment in every case should be to save the injured extremity; however, we feel that, after the viability of the injured extremity has been maintained, the idea of "saving" the extremity, without regard for function, can be carried to an extreme that jeopardizes the welfare of the patient socially, mentally, and economically. For these reasons, one should not lose sight of the proposed functional result or ignore the time necessary for reconstruction.

The final decision on many cases, in which numerous surgical procedures had been done for repair of war injuries, had to be made by the staff of this Amputation Center after the case had been thoroughly studied, and after consultation with other specialists. It is

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difficult to lay down definite indications for amputation following failures in reconstructive surgery as each case must be studied thoroughly from social and economic, as well as from mental and physical, standpoints We shall, however, cite a few general indications

REASONS FOR AMPUTATION

In a majority of instances, various combinations of infection and of injuries to bone, muscle, blood vessels, and skin were present, rather than injury to a single tissue The authors have tried to arrive at the primary and secondary indications that influenced the decision to amputate

Osteomyelitis

Amputation, as the treatment of osteomyelitis *per se*, is rarely advocated In 111 cases (44 per cent) of this group, however, long-standing, chronic osteomyelitis was the primary cause for amputation Of these, 81 per cent had associated bone defects, non-union, and structural deformity, 19 per cent had nerve damage, 19 per cent had circulatory impairment, and 67 per cent had moderate to large skin defects superimposed on the bone infection Of cases in which amputation was done primarily for other causes, osteomyelitis was present in 20 per cent

The medical literature contains many enthusiastic reports of the treatment of osteomyelitis by means of saucerization, followed by the use of skin grafts, muscle grafts, and bone chips, as well as treatment by the Orr method, with or without antibiotics The authors do not advocate amputation to replace these methods, which are effective in rehabilitating the patient in a vast majority of the cases that require such treatment, but cite some instances in which these treatments failed In each amputation for chronic osteomyelitis, the patient had previously undergone recognized treatment with unfavorable results Most of the infected areas had drained almost continuously for over two and one-half years, with little or no benefit from the procedures mentioned The majority of patients in this group had had between three and fifteen sequestrectomies and saucerizations Key and others have strongly advocated amputation in this type of case

Bone Defect or Shortening

Although a bone defect or shortening of an extremity is not an indication for amputation, the importance of shortening is greatly emphasized when there is osteomyelitis, massive skin defect, or paralysis in addition to a bone defect The condition may well be a primary indication for amputation This fact becomes more apparent after prolonged treatment, when there is a probability of a poor functional result Regarding this problem Kirk has stated "Persistent nonunion in bones of the lower extremity in the adult, particularly where there is marked loss of substance and when repeated autogenous bone grafts fail, must be considered an indication for amputation" Many of the authors' cases were in this group, osteomyelitis being the most prevalent cause of failure In an extremity with several inches of shortening, associated with major skin, bone, nerve, and joint dysfunction, we believe that a well-fitting prosthesis is more efficient and less unsightly than a cumbersome built-up shoe Sixty amputations (24 per cent) were done primarily for large bone defects Bone defects were a secondary cause for amputation in 117 (47 per cent) of these war injuries In forty-three (71 per cent) of the sixty cases with large bone defect, there was associated osteomyelitis, in 50 per cent , a major skin defect, in 17 per cent , nerve involvement, and in 11 per cent , circulatory impairment

Skin Defects

Patients were often transferred to this Hospital from Plastic Centers, where months or years had been devoted to attempts at skin-grafting a large area in preparation for reconstructive bone surgery of an extremity Most of these cases showed failure after

Fig 1-A

Fig 1-B

Fig 1-C

Fig 1-D

Fig 1-A Massive destruction of the femur, five months after the patient had been struck by machine-gun fire He received the routine treatment, consisting of debridement, antibiotics, hip-spica cast, balanced suspension-traction for one year, and numerous sequestrectomies because of osteomyelitis The wounds about the knee were closed secondarily, and an arthrodesis of the right knee was performed one year after injury, a fibular graft being used After eight weeks in a hip-spica cast, the patient was given an ischial-bearing brace, a built-up shoe was added five months later Painful motion and drainage developed in the knee, and the patient was transferred to Walter Reed General Hospital

Fig 1-B Ischial-bearing brace with shoe built up 4 inches (10 centimeters) Amputation was decided upon because of (1) partial anaesthesia of the foot, (2) fibrous ankylosis of the ankle, (3) incomplete paralysis of the anterior group of leg muscles, (4) 5 inches (12 5 centimeters) of shortening of the extremity, (5) incomplete, painful fusion of the right knee, and (6) comminuted fracture of the lower third of the femur and its condyles, with persistent drainage from underlying chronic osteomyelitis A mid-thigh amputation was performed, twenty-two months after the injury

Fig 1-C Shows patient after amputation and fitting with right-thigh prosthesis

Fig 1-D Patient was able to wear his prosthesis as long as sixteen hours daily If the arthrodesis had been successful and the osteomyelitis had been eradicated, he would have been left with an extremity 5 inches (12 5 centimeters) too short, a stiff knee and ankle, partial loss of sensation over the foot, and a cumbersome, heavy, built-up shoe This combination is neither so functional nor so comfortable as a good above-the-knee amputation with a well-fitting prosthesis

Fig 2-A

Fig 2-B

Fig 2-C

Fig 2-A and 2-B This patient had sustained shell-fragment wounds of the right leg and knee, a compound fracture through the middle third of the right tibia, and incomplete section of the common peroneal nerve Osteomyelitis developed and was treated by saucerization, followed by split-thickness skin-grafting, three months after the injury The gap of 9½ inches (21 centimeters) in the tibia was bridged by transfers of the adjacent fibula, four and eight months later Following the second transfer, the skin over the anterior surface of the leg sloughed Pinch grafts were applied later with partial success Osteomyelitis developed, with sequestration of the proximal portion of the fibular graft Several sequestrectomies were done without improvement

When the patient was transferred to Walter Reed General Hospital, eighteen months after injury, he had multiple draining sinuses and large skin defects with large amounts of scar tissue interposed, incomplete peroneal paralysis, a tibial bone loss of 21 centimeters, ankylosis of the ankle in moderate equinus, and 2 inches (5 centimeters) of shortening of the right leg

Fig 2-C Roentgenograms taken through cast show massive tibial defect and unsuccessful fibular graft More years could have been spent in reconstructive surgery in an effort to eradicate the infection, obtain good skin coverage, improve circulation and nerve function, and perform bone-grafting The functional outcome would have been dubious, even had these procedures been carried out

Fig 2-D Roentgenogram of stump after open amputation had been performed, just proximal to the area of osteomyelitis of the right tibia

Fig 2-D

Fig 2-E

Fig 2-F

Fig 2-E Short below-the-knee stump after plastic revision and healing

Fig 2-F Prosthesis has an ischial weight-bearing thigh corset which carries most of the weight, leaving the short stump mainly for activation With this short stump, the patient may require a bent-knee prosthesis or even a thigh amputation in future years With the ischial-bearing prosthesis, however, his present stump should assure many useful years

repeated attempts at pedicle grafts or full-thickness grafts Many excellent grafts had finally to be discarded, due to the multiplicity of other indications for amputation Much

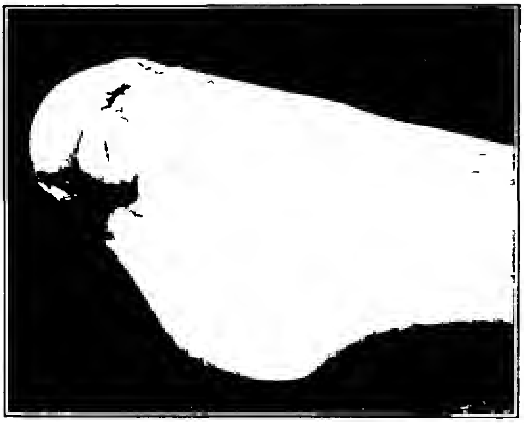

FIG 3-A

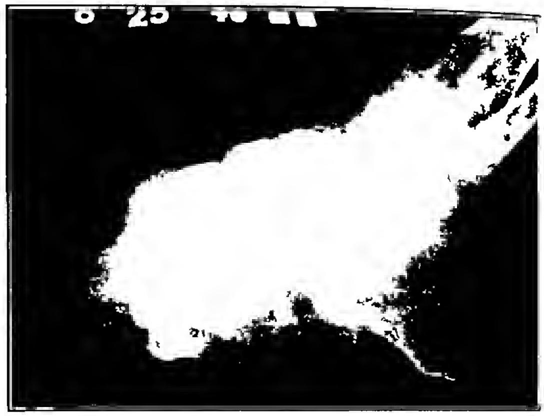

FIG 3-B

Fig 3-A This patient was struck by shell fragments, receiving a laceration of the right popliteal artery with subsequent ligation Ischaemic gangrene developed Amputation was performed through the first, second, and third tarsometatarsal joints and through the bases of the fourth and fifth metatarsals, three months after injury One month later, the granulating stump end was covered by split-thickness and pinch grafts Seven months after injury, a tube skin graft was begun, this was completed in four months After fitting with a special shoe, weight-bearing was attempted, only to be interrupted by drainage from the skin graft Several sinusectomies, sequestrectomies, and sympathetic blocks were performed

Photograph shows condition of foot upon arrival of patient at Walter Reed General Hospital, twenty two months after injury

Fig 3-B Roentgenogram of partial foot Amputation at a higher level was advised because of (1) marked equinus deformity, (2) inability to bear weight because of pain, even after several months' trial with a special shoe, (3) underlying infection, and (4) pressure necrosis of full-thickness skin grafts, without sensation, over weight-bearing areas After lumbar sympathectomy, a modified or open amputation (done because of an infected field) was performed at the talonavicular and talocalcaneal joints, two years after the original injury A routine Syme amputation was performed, six weeks later

FIG 3-C

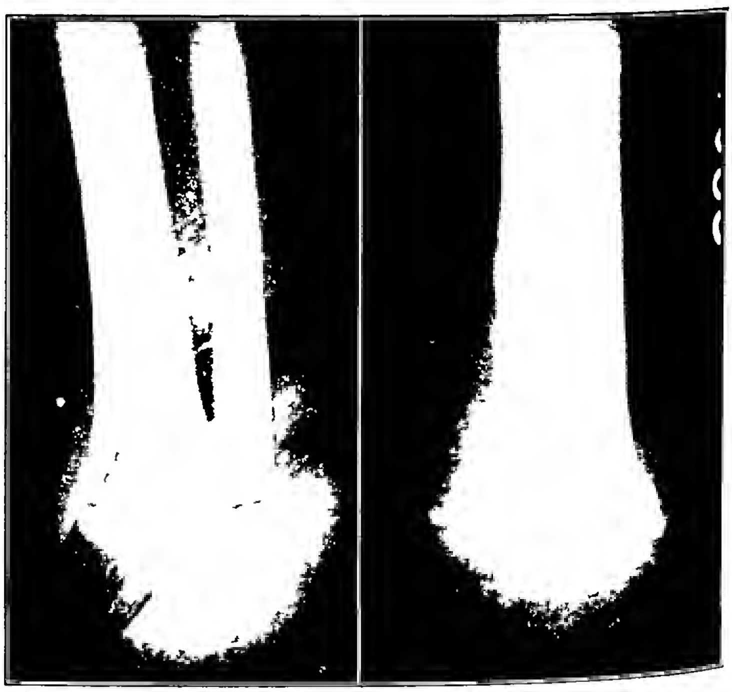

FIG 3-D

Photograph and roentgenograms of healed stump after Syme amputation

time had, therefore, been lost, and the body had been marred by donor-site scars without commensurate functional gain

Large full-thickness grafts on weight-bearing surfaces, especially on stumps of partial feet, are, in our opinion, of limited value The authors followed twenty-two of these cases at Walter Reed General Hospital, in some of which the final grafting operation had been done two to three years before Repeated ulcerations of these grafts occurred, in spite of

every effort to minimize pressure on the critical areas by furnishing the patient with a specially constructed shoe and with special brace attachments

The indications for amputation of extremities with skin defects were

1 Underlying pathological changes too extensive for repair, in spite of adequate skin-grafting,

2 Underlying pathological changes too extensive for repair, with inadequate covering of skin,

3 Repeated unsuccessful attempts at skin-grafting,

4 Unhealthy skin grafts on weight-bearing areas

Absence of skin on an extremity was a primary reason for amputation in only 2 8 per cent of the cases In these cases, almost the entire extremity had been denuded, and several years of split-thickness grafting and pedicle grafting had left a paucity of donor sites, atrophied and scarred extremities, exposed painful nerves, fibrosed muscles, stiff joints, and a meager blood supply Skin deficiency exercised a more important influence as a secondary indication for amputation, the problem existing to a fairly marked degree in 124 cases or 50 per cent of this series

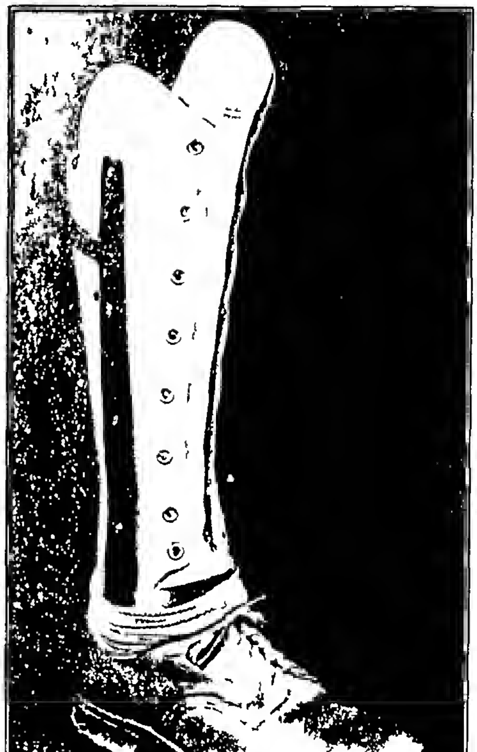

FIG 3-E

Permanent type of prosthesis with which patient was fitted He was discharged two and one-half months after the final amputation (twenty-six and one-half months after the original injury) with the characteristic painless, even gait He was able to walk several miles a day and wore his prosthesis nearly all of his waking hours It is easier to judge in retrospect, however, the authors believe that a Syme amputation should have been done nearly two years earlier

Partial-Foot Amputations

Reconstructive surgery has definite limitations in partial-foot amputations The only satisfactory partial-foot amputations of major proportion which the authors have seen on Army Amputation Services in the past four years have been metatarsophalangeal disarticulations and transmetatarsal amputations The other commonly discussed amputations through the foot were not of so much functional value as those at the next higher levels,—namely, the Syme amputation or the below-the-knee amputation The authors feel that the optimum functional amputation through the foot demands (1) amputation distal to the bases of the metatarsals, (2) healthy plantar skin with minimum scar tissue, extending anteriorly over the end of the stump to the dorsal skin of the foot, (3) good nerve and blood supply to the entire plantar skin and skin flap, (4) function of the ankle and intertarsal joints, associated with strong leg muscles and negligible shortening of the extremity

Partial-foot amputations, which were done in twenty-two (8 8 per cent) of this group of 250 cases, have fallen into disrepute for the following reasons

1 The essential tripod, formed by the calcaneus posteriorly, the heads of the first and fifth metatarsals anteriorly, and the great toe for balancing and walking, is lost or covered by scar tissue on the plantar surface

2 Amputations through the foot at or proximal to the tarsometatarsal articulation have led to muscle imbalance The insertions of the toe extensors—peronaeus longus, peronaeus brevis, and peronaeus tertius—and the major insertion of the tibialis anterior

Fig. 4-A

Patient received flak wounds, sustaining a compound comminuted fracture of the right radius and severe injury to the ulnar, median, and radial nerves. Treatment in a prison hospital consisted of draining of abscesses of right forearm. These roentgenograms were taken after the patient's return to the United States, five months after injury. Physical findings were multiple draining sinuses of right forearm, complete paralysis of radial and median nerves, and partial paralysis of ulnar nerve. The infection of the forearm subsided after numerous sequestrectomies, in addition to local and parenteral therapy. Eleven months after injury, the remaining distal radial fragment was fused at operation to the distal end of the ulna. Fifteen months after injury, the median and radial nerves were explored and found to be damaged irreparably.

Fig. 4-B

Condition of forearm and hand upon arrival of patient at Walter Reed General Hospital, two years after injury. Amputation was recommended because of (1) complete absence of function of median and radial nerves and only partial function of ulnar nerve below the elbow, (2) irreversible atrophy of forearm and hand muscles, (3) fibrous ankylosis of wrist, hand, and finger joints, and (4) marked vascular changes throughout hand.

had been removed. This left the powerful posterior leg muscles unopposed, thus producing a marked equinovarus deformity of the foot. Although some still favor the Lisfranc amputation (namely, a tarsometatarsal disarticulation), the authors believe that the Lisfranc and Chopart amputations are of much less value from a functional point of view than the Syme amputation or the below-the-knee amputation. The Lisfranc, Chopart, and Pirogoff amputations should be considered as having only historical significance.

Fig 4-C

Fig 4-C Healed below-the-elbow stump Amputation was performed over two years after original injury

Fig 4-D After toughening of the stump and strengthening of the arm and shoulder muscles, the patient was fitted with prosthesis He was discharged four months after amputation (twenty-eight months after injury), capable of writing, handling tools, and caring for daily necessities He was better satisfied with his functional hook than he had been with his useless hand

The forearm, in the authors' opinion, should have been amputated as early as evidence of irrevocable nerve damage had been established

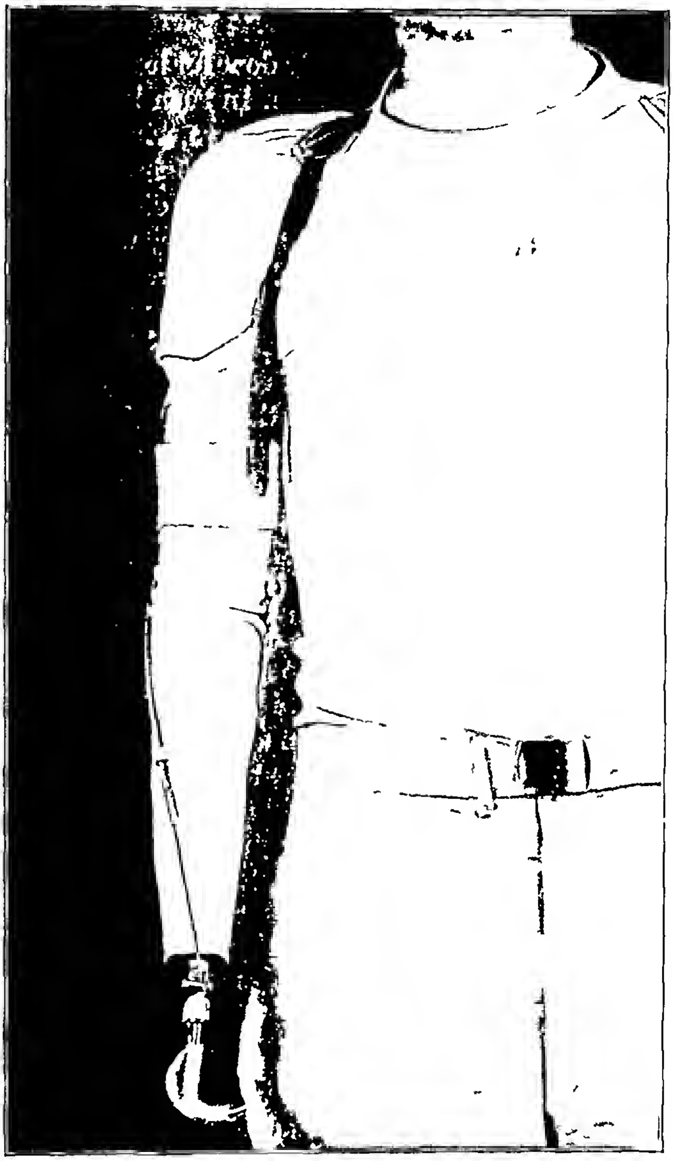

Fig 4-D

3 When weight is borne on scarred, dorsal, or grafted skin with poor sensation—skin that is not accustomed to full weight-bearing—ulceration or painful callus formation results

4 No prosthesis has yet been devised which will completely overcome the muscle imbalance and provide a coordinated and painless gait after the Lisfranc and Chopart procedures

Some have advocated ankle fusion, triple arthrodesis, section of the Achilles tendon, tendon transplants, and full-thickness skin grafts in an effort to make partial-foot amputations satisfactory In patients we have seen who had undergone these procedures, the pain and disability had not been relieved, and the full-thickness grafts became ulcerated, forcing the patients to spend most of their time on crutches or in wheel chairs We feel that such time-consuming procedures, leading to functional failures, are contra-indicated

Difficulty has been experienced in convincing some patients with an unsatisfactory partial foot that reamputation was needed After a week or so of witnessing the facility with which Syme and below-the-knee amputees handled their painless stumps in well-fitted prostheses, these patients were convinced of the need

Nerve Impairment

Amputation was frequently done for loss of nerve function, sciatic and brachial-plexu injuries being the most common. In such instances, the patients had undergone one o more explorations of the impaired nerve, when possible. Some nerves were repaired, other were found to be damaged irreparably. Joint ankylosis, fractures, and infection often pre vented nerve repair. When regeneration did not occur within a reasonable length of time after repair, and when further neurosurgery was deemed inadvisable by the neurosurgeon, amputation was recommended. The authors consider a useful prosthesis more desirable than an anaesthetic, ulcerated, deformed, non-weight-bearing foot (or useless hand) with ankylosis of the knee and ankle and atrophied muscles of the leg and foot.

Primary nerve impairment accounted for forty-four (18 per cent.) of the amputation in this series; it was a contributing cause for amputation in 14 per cent. of the case. Twenty-three per cent. of extremities with nerve impairment had associated osteomyeliti, 32 per cent. had definitely impaired circulation, 39 per cent. had bone defects, and 39 per cent. had reasonably extensive skin defects or trophic ulcers.

Injury to Major Vessels without Gangrene

Major vessels which had been injured without gangrene immediately resulting often provided circulation sufficient to maintain life in an extremity, but insufficient for healing of associated infection or for maintaining the part during or after reconstructive surgical procedures. In many cases, even after sympathectomy, the skin repairs, bone grafts, and arthrodeses failed, and the patients were left with pulseless, swollen, cold, hypersensitive feet and atrophic or ulcerated skin.

Although minor circulatory problems were present in a vast proportion of the 250 cases, blood supply figured strongly in the decision for amputation in only six cases (2.4 per cent.), secondarily in fifty-one cases (20 per cent.).

FINAL EVALUATION

After consideration of these factors, it is apparent that the decision to amputate should, when possible, rest on the opinions of several men experienced in reconstructive and amputation surgery, who have studied the individual case.

After surgical evaluation had been completed, the standard procedure was to ask the patient his desire and opinion. In rare cases, usually of upper-extremity injuries, the patient preferred a useless extremity to a useful prosthesis. No patient of this group had amputation without his full approval. Although some of the amputated extremities could have been saved by further extensive reconstructive surgery, the extremity would have been functionally not so valuable to the patient as a prosthesis.

The policy of the Army Medical Corps has been to return each soldier to active duty or to civilian life in the best possible physical condition, regardless of expense or length of treatment. This situation is ideal for reconstructive surgery. Even under these excellent conditions, however, the 250 patients in this group independently preferred amputation to a protracted hospital course with dubious results. Amputation, however, was by no means elected in all cases referred to us. Many patients thought severence of the extremity synonymous with a rapid termination of their difficulty. The authors did not hesitate to correct this delusion and to convince them that continuation of reconstructive surgery was important to their welfare, when a satisfactory functional result could be expected in a reasonable length of time. This group of patients did not have to be persuaded when the staff thought amputation advisable.

When prolonged treatment involves many of the most productive years of a patient's life and his own extremity, his viewpoint must be considered. It is difficult to manage a unwilling patient, undergoing full-thickness skin-grafting or encased in plaster. The pa

tients who were most unwilling were those who had already been hospitalized for years, and whose outlook for functional recovery was still very doubtful

Failures occur in amputation surgery, as in reconstructive surgery, and they should be prevented when possible When amputation is indicated, the surgeon must select the proper type for the case being considered Meticulous hemostasis and atraumatic technique in the handling of the freshly severed tissues[3] must be supplemented by preoperative and postoperative care, followed by physical therapy The surgeon must have knowledge of the prostheses available, of their mechanics and function, and of the proper time to send the patient to be fitted[4] He also must encourage correct early walking habits, if possible, and watch the condition of the stump in this critical period while the skin is still tender If these principles are not observed, the amputating surgeon, like the reconstructive surgeon, will obtain poor functional or rehabilitative results Our poorest rehabilitative results have been those necessitating hip and shoulder-joint disarticulations and high thigh and arm amputations, as prostheses for these amputations are still not satisfactory

CONCLUSIONS

1 Amputation as an end result is better than a painful or useless extremity without hope of restored function

2 The functional end result of extremity reconstruction and the time necessary to obtain this result must be kept constantly in mind

3 Amputation in selected cases, when carried out in the proper manner, and when the limb is fitted with a correct prosthesis, should be considered a form of constructive treatment

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TABLE I

FINDINGS FROM STUDY OF SIXTY-FIVE MENISCI

Case No	Age and Sex	Joint	Volume of Meniscus (*Cubic centimeters*)		Initial Length between Clamps (*Millimeters*)		Weight Needed to Produce Fracture (*Pounds*)		Type of Fracture	
			Medial	Lateral	Medial	Lateral	Medial	Lateral	Medial	Lateral
1	32 M	Left			28		52		Oblique	
2	58 M	Left			53	60	56	54	Oblique	Transverse at junction of upper and medial thirds
3	38 M	Left			52	45	79	92	Oblique	Spiral
4	54 M	Right			46	37	84	94	Oblique	Spiral
5	68 F	Left	3.8	3.4	56	40	43	93	Oblique at junction of upper and medial thirds	Spiral
6	48 F	Right	2.4	2.3	35	39	71	84	Oblique	Spiral
7	58 M	Left	3.3	2.5	40	34	59	78	Oblique	Spiral
8	61 M	Right	4.6	4.7	51	52	75	107	Transverse	Transverse
9	37 M	Left	1.5	2.8	42	30.5	40	65	Oblique	
10	42 F	Left	2.2	2.0	36.5	41	70	60	Oblique	Spiral
11	58 M	Left	2.8	2.1	40	38	39	59	Oblique	Spiral
12	71 F	Right	3.9	3.0	40	35	79	73	Transverse	Spiral
13	46 M	Right	3.7	3.0	32	37	73	85	Fork-shaped	Oblique
14	75 M	Right	3.7	3.8	59	46	18	63	At weak spot	Oblique
15	57 M	Left	4.0	2.6	53	34	40	Slipped at 75	Almost transverse	
16	45 F	Right	2.5	2.4	37	19	53	53	Oblique	Transverse
17	58 M	Right	3.0	2.9	37	32	45	75	Oblique	Spiral
18	53 F	Right	2.8	3.0	39.5	36	70	78	V-shaped	Spiral
19	M	Right	4.2	2.5	52	48	58	Slipped at 77	Transverse	
20	75 M	Left	4.1	3.0	47	43	47	79	Oblique	Oblique
21	63 M	Left	4.5	3.0	63	39	44	57		Almost transverse
22	73 M	Right	4.5	3.5	53	31	28	70	Transverse	Spiral
23	22 M	Right	3.3	2.8	45	31	88	80	Oblique	Spiral
24	54 M	Left	5.1	2.9	47	44	59	60	V-shaped	Oblique
25	61 F	Left	2.0	2.3	30	32	39	70	Spiral	Oblique
26	81 M	Left	4.8	4.5	48	35	60	64	Transverse	Oblique
27	19 F	Right	1.7	1.9	32	31	65	80	Oblique	Spiral
28	73 F	Left	4.0	3.2	55	39	54	59	Oblique	Oblique
29	32 F	Left	3.2	2.8	50	36	72	88	Oblique	Spiral
30	78 M	Left	3.8	3.4	52	43	45	67	Oblique	Oblique
31	17 F	Right	2.9	2.1	40	37	60	Slipped at 82	Oblique	
32	10 F	Right	3.1	2.8	38	35	43	78	V-shaped	Spiral
33	47 M	Right	4.7	4.5	52	50	22	72	Oblique	Spiral

TABLE II

FINDINGS FROM STUDY OF MENISCI OF ANIMALS

Animal No	Joint	Volume of Meniscus (*Cubic centimeters*)		Initial Length between Clamps (*Millimeters*)		Weight Needed to Produce Fracture (*Pounds*)		Type of Fracture	
		Medial	Lateral	Medial	Lateral	Medial	Lateral	Medial	Lateral
1	Right			12	12	50	50	Transverse	Oblique
	Left			11	12	47	48	Transverse	Oblique
2	Right			9	12	42	35	Oblique	Transverse
	Left			9	11	34	38	Spiral	Transverse
3	Right			12	12	34	25	Transverse	Transverse
	Left			11	12	32	29	Oblique	Transverse
4	Right			10	8	27	35	Transverse at junction of medial and lower thirds	Transverse
	Left			14	14	29	35	Transverse at junction of medial and lower thirds	Oblique
5	Right			12	15	31	23	Transverse	Transverse
	Left			9	11	35	25	Oblique	Transverse
6	Right			14	15	40	50	Transverse	Transverse
	Left			15	13	42	49	Transverse	Transverse
7	Right			11	12	36	51	Spiral	Transverse
	Left			12	14	21	46	Oblique at junction of medial and lower thirds	Spiral
8	Right			10.5	15	40	44	Oblique	Oblique
	Left			9.5	13	42	53	Transverse	Transverse
9	Right	0.5	0.7	12	15	49	56	Spiral	Oblique
	Left	0.5	0.7	13	15	43	54	Transverse	Oblique
10	Right	0.6	0.9	14	17	55	58	Spiral	Transverse
	Left	0.6	0.9	13	14	60	60	Spiral	Oblique

field who was impressed by the relation of the waviness of the elastic fibers to the elasticity of the fibrocartilages He stated that this waviness of the elastic tissue is important in the understanding of the pathological changes, particularly in reference to their rupture He further observed that, with the onset of the degenerative changes in the menisci, the wavy character of the elastic fibers is lost, the fibers become straight and often rupture

It has been established by Tobler, Bennett and his associates, and others th degenerative changes begin between the first and second decades of life Considering th early appearance of the degenerative changes and their effect on the elasticity of th menisci, we can understand the occurrence of traumatic lesions of the structures in th second and third decades of life

There is little doubt that in their normal functions the menisci, especially the medi one, suffer many stresses and strains As Fisher has pointed out, they "assist the latera ligament of the opposite side to resist undue lateral movement" Furthermore, in sudde inward twists or rotation of the femur on the fixed tibia, the medial meniscus is put unde extreme tension Obviously, the weak medial meniscus, rendered weaker by degenerativ changes, would be unable to resist the strain In view of these facts and of our own observa tions, it seems plausible that the inherent weakness of the medial meniscus, in associatio with its shape and structure, is as much responsible for the high incidence of its rupture as its slight attachment to the tibial collateral ligament

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RADIATION OSTEITIS OF THE RIBS

REPORT OF A CASE WITH FRACTURES APPEARING FOUR AND ONE-HALF AND ELEVEN YEARS AFTER THERAPY

BY ERNST A POHLE, M D, AND RALPH C FRANK, M D, MADISON, WISCONSIN

From the Department of Radiology, University of Wisconsin Medical School, Madison

Radiation osteitis has received little mention in the literature Only in recent yea has the growing interest in this phenomenon been reflected by an increasing number articles on radionecrosis of the mandible, the femoral neck, the ribs, and other skele structures

Rib involvement by radiation osteitis does not entail the mechanical proble inherent in involvement of weight-bearing bones However, the task of differentiati such sequelae from metastatic foci makes their recognition imperative The purpose

this paper is to present a case of radiation osteitis in which fractures of the ribs appeared four and one-half and eleven years, respectively, after the initial postoperative roentgenotherapy for carcinoma of the breast

CASE REPORT

H G, a white woman, forty-nine years old, was referred to the Wisconsin General Hospital on April 19, 1937, for radiation therapy following a radical left mastectomy, performed elsewhere on March 29, 1937 A Grade III carcinoma had been removed and axillary metastases were found The patient had been conscious of pain and a lump in the left breast for only two weeks prior to surgery

Using a technique described in detail by Pohle and Benson, postoperative roentgenotherapy was administered to each of four fields daily for eight treatments The fields treated were the supraclavicular, anterior portion of breast, and anterior and posterior axillary regions Similar courses of therapy were given in July and December 1937, in July 1938 and in February 1939 In all, a total dosage of 7,750 r (in air) was administered to each of the four fields treated during that period The patient was well and free from metastases at the time of her last examination, January 12, 1948

On September 30 1941 radiation osteitis and pathological fracture of the anterolateral arc of the left fourth rib were found A routine chest film on September 14, 1940, had been negative for metastasis or radiation osteitis

In a group chest survey on December 30, 1947, the fracture which occurred eleven years following therapy was suspected of being a metastasis, the attending physician, who recognized the true character of the lesion, referred the patient to us chiefly for reassurance * Our roentgenograms, taken on January 12, 1948, revealed partial healing of the previously discovered fracture in the fourth rib and the appearance of radiation osteitis and pathological fracture in the anterolateral arc of the left third rib (Fig 2)

FIG 1

FIG 2

Fig 1 Roentgenogram taken on April 4, 1942, demonstrating radiation osteitis and pathological fracture of the anterolateral arc of the left fourth rib, changes which had been detected first on September 30, 1941

Fig 2 Roentgenogram of January 12, 1948, showing healing of the fracture in the fourth rib and appearance of radiation osteitis with associated fracture in the anterolateral arc of the left third rib The third rib was not involved until eleven years after the initial therapy had been administered

DISCUSSION

In a previous article on this subject by Paul and Pohle, the literature was reviewed and the roentgenographic findings were described A detailed review will not be repeated, but a few comments are indicated

* The last roentgenogram of the chest on file before December 1947, was taken on March 3, 1945, and was reported as negative

Bone, even adult bone, can no longer be regarded as relatively insensitive to irradiation Its calcium content results in increased absorption of rays entering it as compared to less dense tissues Slaughter stated that, according to Failla, this increase amounts to 30 to 40 per cent The mineral content also produces a greater amount of soft secondary radiation than is found in other tissues Warren regards bone as more sensitive to irradiation than skin or mucous membrane

As pointed out by Ewing, the extent of bone involvement varies from minimal reversible changes through sclerosis, fracture, and sequestration, to the most severe type in which secondary osteomyelitis occurs The last is found most frequently in the mandible Radiation osteitis is usually painless, except in mandibular cases with superimposed infection When symptoms occur, they are most often due to mechanical disability arising from involvement of weight-bearing bones Since rib involvement is almost always asymptomatic and painless, the fear of producing this complication should never interfere with the administration of an adequate course of therapy in breast carcinoma or other lesions of the chest wall where irradiation will involve the ribs

Spontaneous healing of fractures due to radiation osteitis apparently depends upon the severity of bone involvement and the degree of obliterative endarteritis inherent in the process Roentgenographically, the first change is the transverse irregular fracture line, appearing in the anterior or anterolateral arcs of the upper ribs Malalignment may be present and the bones are usually osteoporotic Bone sclerosis may appear later In case of healing, the bones are increased in density

Recognition of the true nature of the lesion is of prime importance The absence of any history of trauma and the asymptomatic nature of the lesion distinguish it from a traumatic fracture More difficult, and more important, is the differentiation from a metastatic focus The transverse fracture line, almost constant location of the lesion in the anterolateral arcs of the third to the fifth ribs, slow progression, and tendency to heal either by bony union or eburnation of the ends of the fracture fragments, as opposed to the moth-eaten rarefaction or destruction seen in metastatic disease, aid in the differential diagnosis

The time interval between therapy and the appearance of osteitis has not been reported adequately in the literature It is becoming increasingly apparent that radiation osteitis is a lesion which may appear at greatly prolonged intervals following irradiation Friedmann has reported a case in which rib fractures occurred five and seven years after the start of therapy for breast carcinoma Therapy was administered before and after radical mastectomy, and several local metastases were treated within a period of three years The total amount of irradiation, therefore, was far greater than usual

Wammock and Arbuckle, using interstitial radium therapy for breast carcinoma and employing an average of 22,000 milligram-hours per patient, reported ten cases, all free of carcinoma for periods ranging from four to nine years, and all with rib fractures which appeared from eleven months to seven years after the start of therapy

Eight cases of radiation osteitis, five with fracture of the clavicle and three with rib fracture as sequelae to therapy, are reported by Slaughter The time interval between therapy and detection of osteitis in his cases varied from one to sixteen years However the time of onset of the complication was not determined, since the osteitis was usually an accidental discovery, no progress films having been taken at regular intervals In the clavicular cases, those with a long interval showed evidence of long-standing involvement Slaughter estimated that the ribs and clavicles received about 2,000 r

Reviewing 2,046 cases of intracranial tumors, Camp and Moreton found five with aseptic necrosis of the calvarium They did not regard this figure as the true incidence of the complication, since not all of the cases reviewed had an adequate follow-up As with rib involvement, radiation osteitis of the calvarium is an asymptomatic process, and fe[ar] of its occurrence should not be a deterrent to adequate therapy In their five cases th[e]

longest interval between therapy and changes in the calvarium was twelve years, the time of onset being proved by intermediate films In two cases with detection of the involvement at fourteen and seventeen years, the actual time of onset was not determined

Hatcher reported a woman treated for breast carcinoma, following mastectomy, through anterior and lateral portals to the right shoulder The quantity of irradiation was unknown, but no skin changes occurred Eleven years later chest pain developed and, after further therapy, a chondrosarcoma of the anterior portion of the right seventh rib was resected Although Hatcher believed the sarcoma to be related etiologically to the irradiation, we cannot but doubt such a relationship The occurrence of bone sarcoma in therapeutically irradiated tissues is encountered so rarely that its occurrence could be considered merely coincidental In addition, the anterior segment of the seventh rib receives only a small amount of irradiation with the usual techniques employed in the therapy of breast carcinoma Most of our patients have shown the changes of radiation osteitis only in the third to the fifth ribs

CONCLUSIONS

1 Radiation osteitis of the ribs associated with pathological fracture is a slowly developing lesion which may appear at varying intervals following initial irradiation The eleven-year interval in the case presented is believed to be one of the longest reported in the literature

2 Healing of such fractures may occur, but the process is very slow, as exemplified by the presence of only partial healing in one such fracture during a six-year observation period

3 The importance of distinguishing radiation osteitis from metastatic carcinoma should be emphasized

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THE TREATMENT OF NON-UNION OF FRACTURES OF THE MEDIAL MALLEOLUS

BY SAM W. BANKS, M.D., CHICAGO, ILLINOIS

From the Department of Orthopaedic Surgery, Northwestern University Medical School, the Chicago Memorial Hospital, Chicago, and Hines Veterans Hospital, Hines

The purpose of this paper is to describe a bone-grafting technique for use in cases of symptomatic non-union of the medial malleolus. Not all pseudarthroses of the medial malleolus require treatment. A strong fibrous union with the fragment in good position may be compatible with full function of the extremity and may produce no symptoms. On the other hand, corrective surgery is indicated in the presence of disabling symptoms. These consist either of pain and swelling over the malleolus, an associated posterior tibial tenosynovitis, or instability of the ankle.

TECHNIQUE OF OPERATION

The bone is exposed subperiosteally and the deltoid ligament is isolated beneath the deep fascia. All fibrous tissue between the tibia and the malleolus is excised. The fragments are freshened so as to expose cancellous bone by removing the bone at the site of non-union in a wedgelike fashion, with the apex at the surface of the ankle joint and the base outward. This preserves a maximum amount of the articular surfaces. The fracture of the malleolus is reduced, and the bone is held by towel clips or tenaculum forceps while a metal screw, one and three-quarters inches long, is passed upward through the malleolus from its tip into the tibia.

The triangular defect between the malleolus and the tibia is packed with cancellous bone obtained from the tibia through a window at the proximal end of the wound. A block of cortex, one and one-half inches square, is removed, as shown in Figure 1. The bone is undercut in such a way that the block will not fall into the medullary cavity of the tibia when it is replaced. The wound is closed in layers and a toe-to-knee cast is applied, with the foot in sufficient varus to relax the deltoid ligament.

POSTOPERATIVE CARE

The plaster is changed in fourteen days, when the sutures are removed, and a walking iron is incorporated in the new cast. Partial weight-bearing with crutches is permitted during the next two weeks, and full weight-bearing thereafter. Roentgenograms obtained from eight to ten weeks after the operation should show consolidation of the fracture; if so, the cast may be eliminated. Whirlpool baths, massage, and assisted active motion facilitate the final recovery.

Six patients have been treated successfully by this method. The following case reports are characteristic.

CASE 1. R. T., a male, aged twenty-seven, sustained a fracture of the medial malleolus and of the fibula at the junction of its middle and distal thirds, with lateral displacement of the right foot, on November 1?, 1947, when a brick wall collapsed and fell onto his leg. A closed reduction was performed under general anaesthesia immediately after the injury, a plaster splint was worn for seven weeks. The patient returned to work on March 2, 1948, but was unable to continue after two weeks, because of severe pain and swelling over the medial malleolus.

The author first examined the patient on April 19, 1948. Physical and roentgenographic examinations (Figs. 2-A and 2-B) showed non-union of the medial malleolus with persistent slight lateral displacement of the foot. A cancellous bone graft was applied on April 21, and the malleolus was fixed by a metal screw. Roentgenograms (Figs. 2-C and 2-D), taken eight weeks later, showed union of the medial malleolus; at that time the cast was discarded. The patient achieved full painless motion of the ankle and returned to his job as bricklayer.

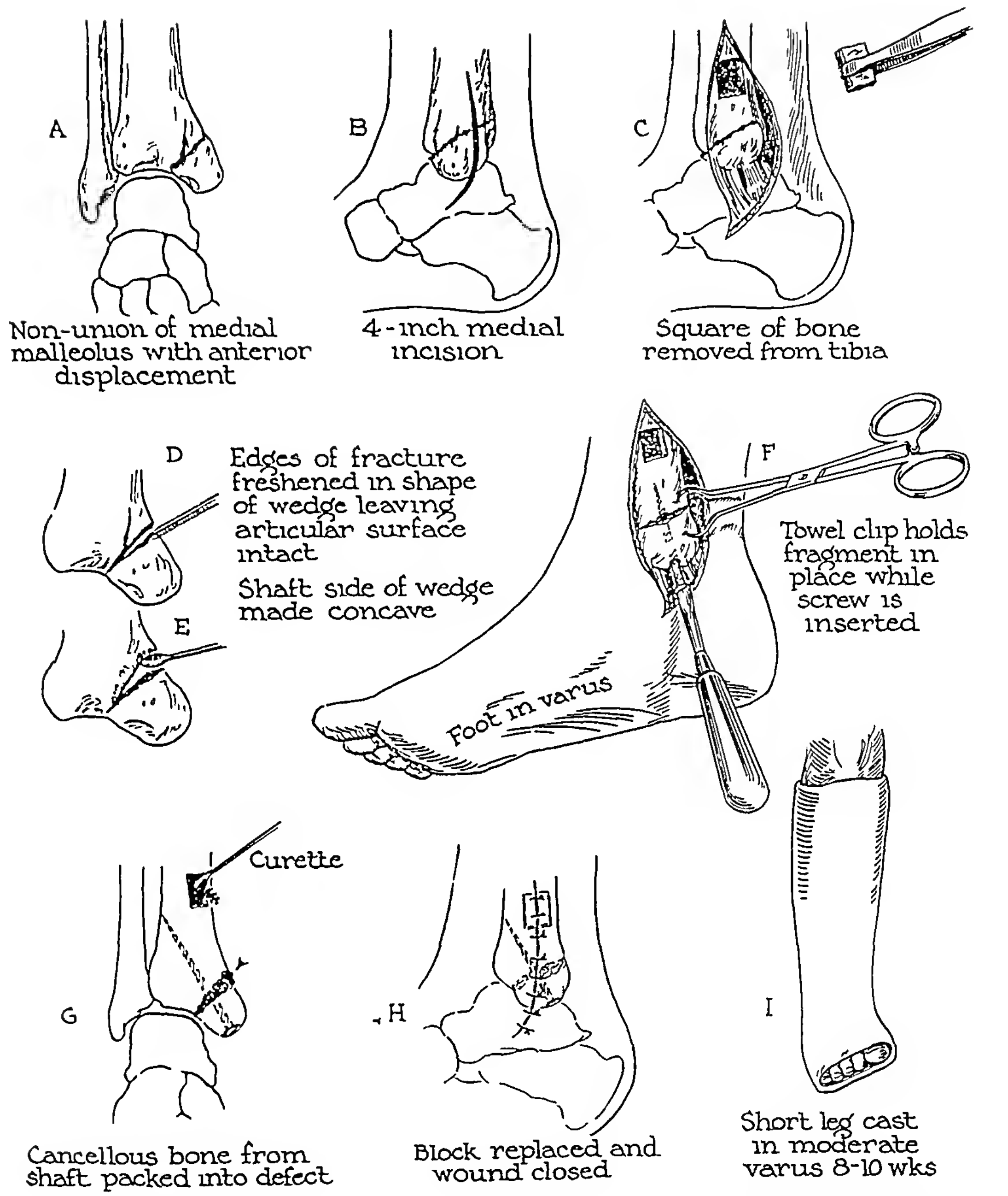

FIG 1

Artist's drawing showing surgical technique for treatment of non-union following fracture of the medial malleolus (Reproduced, by permission of The Year Book Publishers, Inc, from Compere and Banks' *Pictorial Handbook of Fracture Treatment*, Ed 2 Chicago, 1947)

CASE 2 J R C, a male, aged thirty-eight, slipped on uneven ground in September 1945, and sustained a bimalleolar fracture of the left ankle with lateral dislocation of the foot Closed reduction was performed under general anaesthesia at an army hospital, and the ankle was immobilized in a leg cast for fourteen weeks When the patient was discharged from the Military Service, he was told that the medial malleolus had not united, but he refused further treatment

On July 2, 1947, the patient entered Hines Veterans Hospital, complaining of severe pain in the region of the left medial malleolus He had been unable to work as a laborer because of the ankle disability The physical examination showed swelling and tenderness over the posterior tibial tendon behind the malleolus, roentgenograms showed non-union of the medial malleolus (Figs 3-A and 3-B)

On July 5, an open reduction and grafting with cancellous bone were carried out Roentgenograms ten weeks later (Figs 3-C and 3-D) showed union of the malleolus, and the cast was eliminated The screw was subsequently removed, although it was not causing symptoms The final result was excellent, and the patient is now working as a laborer

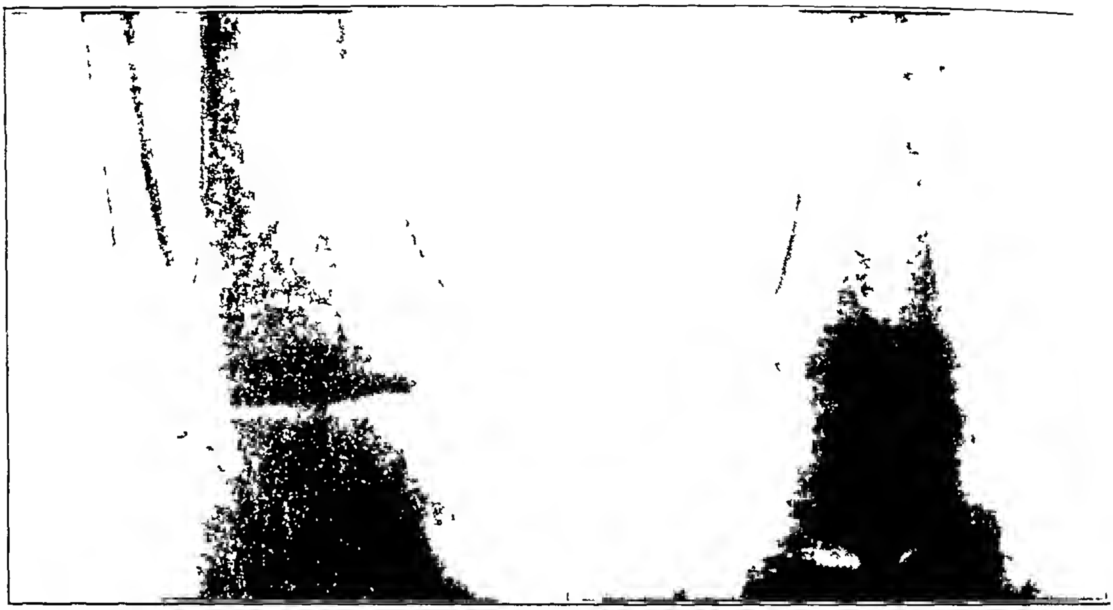

Fig. 2-A Fig. 2-B

Case 1. Anteroposterior and lateral roentgenograms of right ankle show non-union of the medial malleolus with persisting slight lateral displacement of the foot.

Fig. 2-C Fig. 2-D

Roentgenograms obtained eight weeks after operation show union of the medial malleolus. Note the correction of the space between the malleolus and the talus.

DISCUSSION

The treatment of non-union of the medial malleolus, as recommended by Campbell, Watson-Jones, and other authors, employs a full-thickness bone graft, taken from the proximal end of the same tibia through a second incision. The graft is either inlaid so as to cross the fracture site, or is fashioned into the form of a peg and passed upward through the malleolus into the tibia, similar to a metal nail. Although one may expect a high percentage of union when either of these methods is utilized, the technique using

cancellous bone, as described in this paper, offers certain advantages, especially its simplicity of execution. Considerable operating time is consumed in fashioning a cortical-bone peg, it offers poor fixation, and, because of its small caliber, it frequently breaks as the graft is being inserted. At the same time, the total thickness of bone which crosses the site of non-union is small. The inlay type of bone graft is not appropriate for this condi-

FIG. 3-A FIG. 3-B

Case 2. Non-union of the medial malleolus with anterior displacement, twenty-one months after acute fracture.

FIG. 3-C FIG. 3-D

Union of the malleolus was obtained ten weeks after bone-grafting, with return of painless function of the ankle joint.

tion, because of the small size of the malleolar fragment and the difficulty of maintaining fixation of the graft.

In contrast, the use of a metal screw results in strong internal fixation and permits early weight-bearing. Cancellous bone, which is packed into the triangular defect, will not only consolidate and be replaced more rapidly than a cortical graft, but the greater amount of bone transplanted to the site of non-union is more likely to stimulate union. Another important advantage is that the malleolar fragment, which is usually quite small, need not be significantly shortened or approximated to the tibia, except to restore continuity of the articular surface.

Occasionally, because of partial absorption of the malleolar fragment, it cannot be brought into contact with the tibia, in spite of maximum varus of the foot. In two such cases, the author fixed the malleolus with a screw in the best position obtainable and bridged the defect with cancellous bone. The bone must be prevented from entering the joint or coming into contact with the medial articular surface of the talus, for the resulting incongruous surfaces would cause an early arthritis.

The simplicity of the procedure saves considerable operating time, and union has been obtained within eight to ten weeks.

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ISOLATED FRACTURE OF THE CORACOID PROCESS*

BY MAJOR ROY C. ROUNDS, *Medical Corps, United States Army*

Because isolated simple fracture of the coracoid process is seen infrequently, the following case report is presented.

A housewife, who was five months' pregnant, slipped while carrying a two-year-old child and slid down a flight of twenty-two steps on her back. She arrived at the bottom of the stairs in a sitting position, with the child uninjured in her arms. Because of fear of an abortion, she reported to the Obstetric Clinic, in spite of the fact that she was suffering severe pain in the left shoulder and that movements of the left arm were painful.

When seen in the Orthopaedic Clinic, examination revealed ecchymosis and moderate swelling in the left mid-infraclavicular region; this region was extremely tender to pressure. She held the left arm acutely flexed at the elbow, and she supported it against her side with the right arm. Attempts to extend the forearm actively or passively produced severe pain in the region of the coracoid. All motions of the shoulder produced pain.

The only bone injury of the shoulder noted roentgenographically was a fracture through the base of the coracoid process, with complete separation of the coracoid from the scapula (Fig. 1).

Treatment consisted of immobilization of the acutely flexed arm against the chest with a muslin Velpeau dressing, reinforced with adhesive tape. After two weeks, the arm was transferred to a triangular sling, and careful active motion of the elbow and shoulder was encouraged. The sling was discarded two weeks later; at that time all pain had disappeared and roentgenograms showed union of fragments. Final roentgenograms, taken two months after injury, when physical therapy had been discontinued, showed solid union of the fragments in anatomical position (Fig. 2).

* Published under the auspices of The Surgeon General, United States Army, who does not necessarily assume responsibility for the professional opinions expressed by the author.

FIG 1
Appearance of shoulder at time of admission

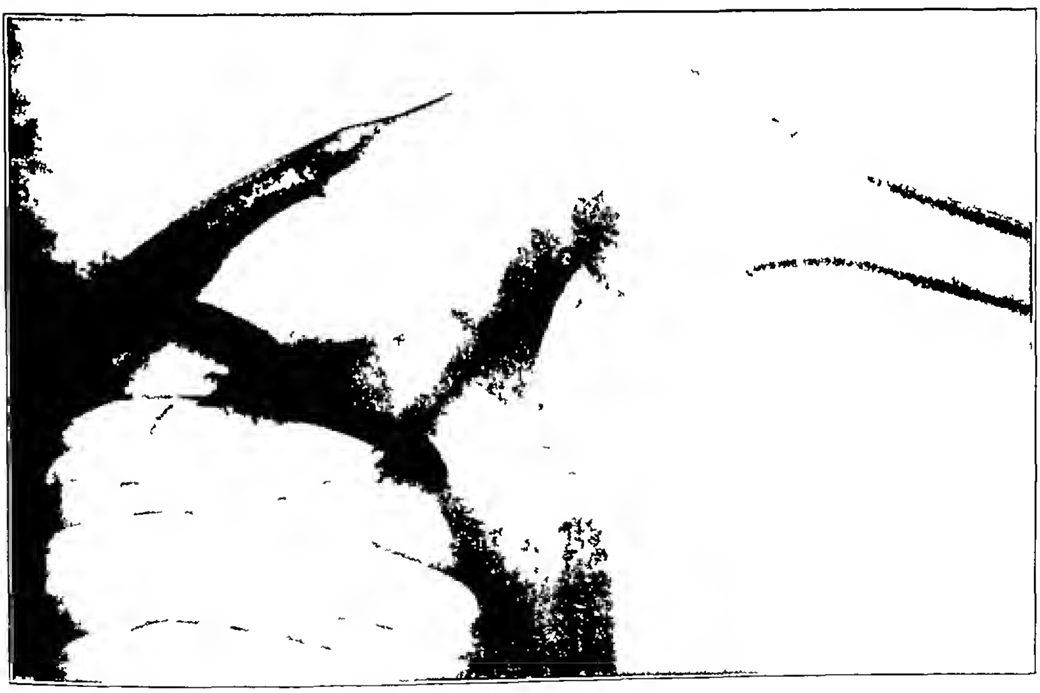

FIG 2
Fragments had united solidly, two months after injury

In this case, the fracture could not have been due to direct trauma, but was the result of indirect forces acting on the coracoid process It was produced either by the force of sudden violent contraction of one or more of the three muscles attached to the process against a fixed scapula, or by sudden motion of the scapula away from these muscles, while they were in a contracted state

SPRING SPLINT TO SUPINATE OR PRONATE THE HAND

BY STERLING BUNNELL, M D , SAN FRANCISCO, CALIFORNIA

Spring or elastic splints coax joints into the position desired more efficiently than d rigid splints In addition, they exercise the limb, improve its nutrition, and mobilize th joints

At present the Funston splint is the most popular for holding the hand in supination

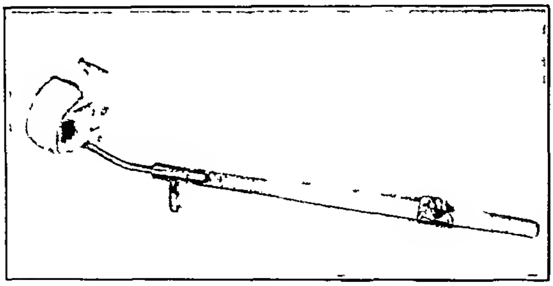

FIG 1

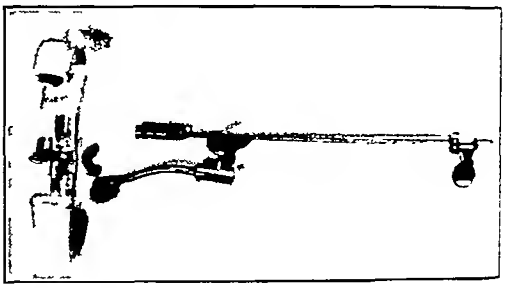

FIG 2

Fig 1 Special attachment which, when clamped to a standard right-angle elbow splint, will produce supination or pronation by a twist of the spring
Fig 2 Attachment dismantled to show cuff, axle and sleeve, torsion spring, and clamp

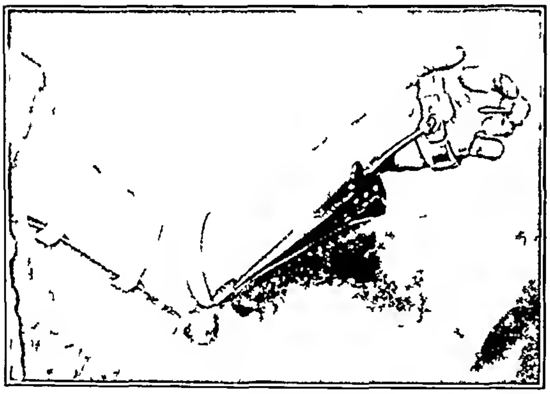

FIG 3

FIG 4

Fig 3 The hand is twisting the spring in the direction of pronation
Fig 4 The spring has rotated the hand into supination

It consists of a right-angle iron along the medial side of the arm, cuffs are fastened to th arm, and a flat cuff at the end holds the hand

A simple device that may be attached to a standard right-angle elbow splint is shown in Figure 1 A springy force of any desired amount, in supination or pronation, is produced by twisting a ribbon of spring steel (10 by 0 5 by 035 inches in size) The adju ment is by a set screw, which holds an axle in the desired position

The strip of spring steel is fastened by a clamp at its proximal end to the medial ed of the upper portion of the forearm piece of a standard right-angle elbow splint A padd flat cuff, adjustable to fit, encircles and controls the hand A rod, curved to fit along th front of the dorsiflexed wrist, is fastened to the cuff by one central bolt in the palm Th short rod terminates proximally in a sleeve A short axle, riveted to the end of the ribb of spring steel, fits into this sleeve The spring is twisted to give the desired degree of fo in either supination or pronation (Figs 3 and 4), and the axle on the spring is fixed in th position by a butterfly setscrew in the sleeve The torsion force is transmitted to the ha by the flat cuff The central bolt in the hand cuff allows the cuff to be turned so as to f either hand

FORCEPS FOR GRASPING AND HOLDING BONE PLATES

BY MEYER M. STONE, M.D., NEW YORK, N. Y.

The grasping and holding forceps presented here (Fig 1) has proved helpful as a simple and secure method of handling a bone plate for fixation of a fracture The forceps will facilitate the non-touch technique, and has many advantages for those who do not follow this technique The operating field is unobstructed by hands holding the plate in

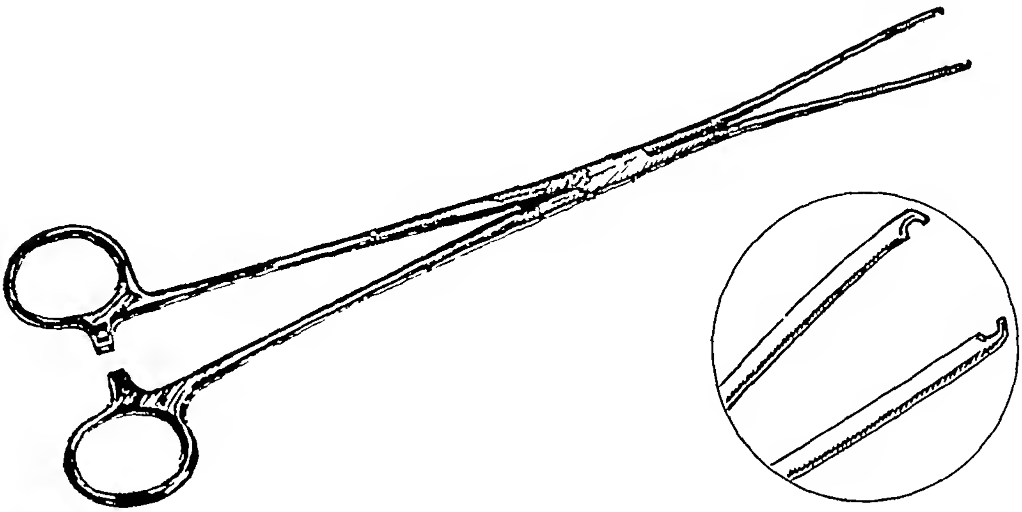

Fig 1
Forceps, with detail of tip in circle

the wound, and there is less danger of dropping the plate when held by the forceps than when it is held in the wet gloved hand or by the hemostat

The forceps facilitates the handling of the bone plate and its application to the bone at the fracture site The plate is held in place by an assistant, who is enabled to keep well out of the operator's field until the plate has been secured by one of several bone clamps, prior to insertion of the screws When the plate is held firmly against the bone by the clamp, the forceps can be easily disengaged and removed by unlocking the ratchet

Marring or scratching of the bone plate is reduced to a minimum, due to the design and construction of the instrument It is recommended that the plate be grasped and held at the two end screw holes

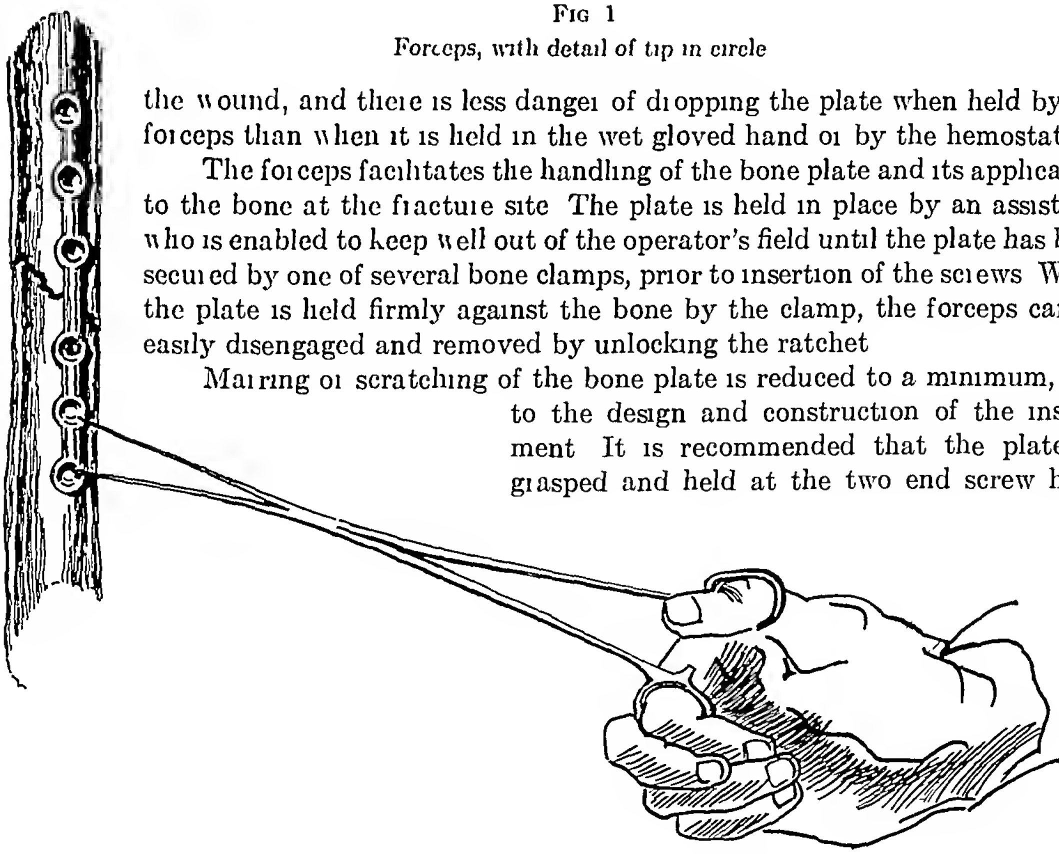

Fig 2
Application of plate to bone surface with forceps, prior to clamping

(Fig 2), since the operator thereby has greater freedom in clamping the plate to the bone

The forceps has been used by members of the surgical staff at the Beekman-Downtown Hospital, who have found it to be of considerable practical value

LEGG-PERTHES DISEASE AND SLIPPED EPIPHYSIS IN THE SAME PATIENT

A Case Report

BY HERBERT R MARKHEIM, M D , BALTIMORE, MARYLAND

*From Kernan Hospital *, Baltimore*

In a review of a series of fifty cases of Legg-Perthes disease, one case was found in which Legg-Perthes disease developed in one hip while, at a later date, the other hip showed slipping of the capital epiphysis

R M an eleven-year-old white boy, was admitted to Kernan Hospital on May 4, 1934, complaining of a limp on the left side His mother stated that she had noticed the limp for about six months, but that there had been no complaint of pain The past history and family history were non-contributory The patient was well developed and well nourished The spine was straight, but the left side of the pelvis was lower than the right The child walked with a limp, favoring the left lower extremity The left lower extremity was 1 2 centimeters shorter than the right The left thigh measured 2 centimeters less than the right in circumference The left hip lacked 15 degrees of flexion and 20 degrees of abduction when compared to the right hip Internal and external rotation of the left hip were also restricted

The urine showed a trace of albumin, but microscopic examination was negative The red blood-cell count was 4 500,000, the white-blood-cell count was 7,000, the hemoglobin was 75 per cent The serological findings were doubtfully positive on two occasions, and negative the third time Roentgenograms revealed bony destruction of the head and neck of the left femur, with flattening of the head (Fig 1) A diagnosis of Legg-Perthes disease of the left hip was made

Skin traction was applied to the left lower extremity for thirty days Following this period, he remained in bed for ten days while an ischial caliper for walking was being made for the left lower extremity The sole of the right shoe was built up about two inches, and the patient was permitted to walk He was dis-

FIG 1

R M Anteroposterior roentgenogram of both hips Legg-Perthes disease is evident on the left

* Service of Allen F Voshell, M D

changed after two months of hospitalization. The patient was followed in the Clinic, and his brace was discarded after he had worn it for one and one-half years.

In December 1936 the child was again brought to the Clinic by his mother, who had observed that he

FIG. 2

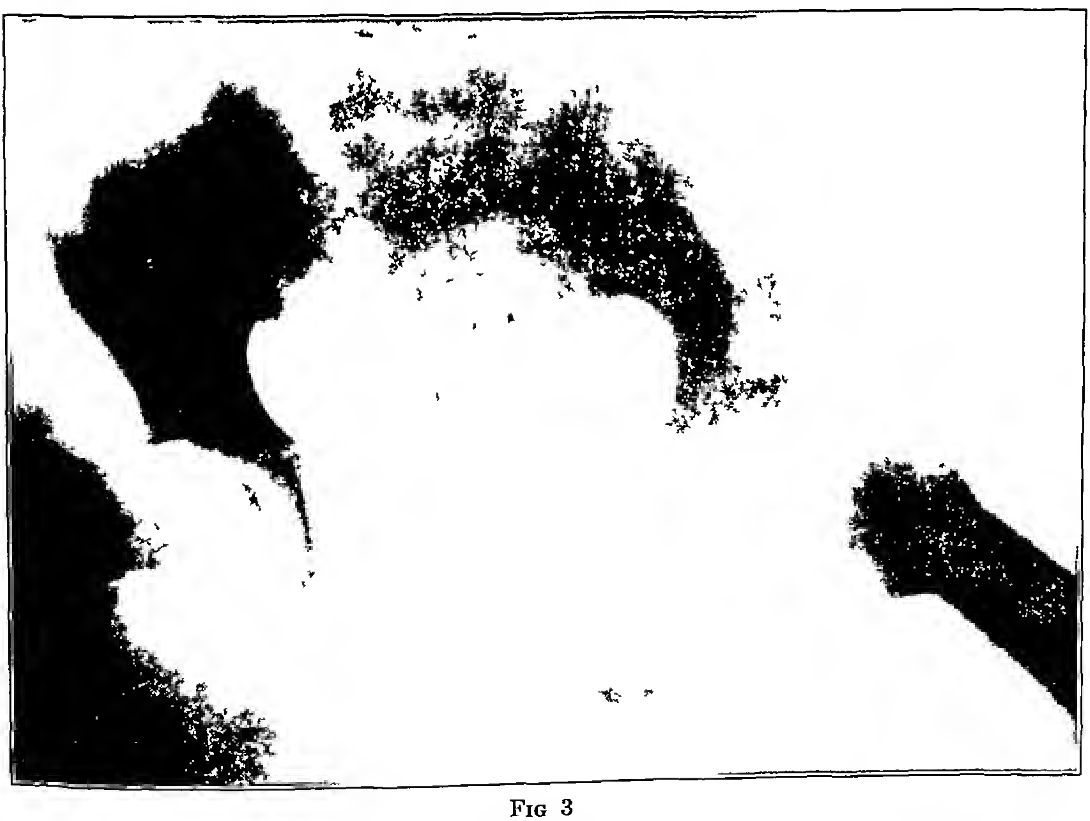

FIG. 3

Anteroposterior and lateral roentgenograms of both hips, taken two years and eight months later, show Legg-Perthes disease of the left hip and slipped epiphysis of the right hip.

was "knock-kneed" On January 2, 1937, he was readmitted to the Hospital The boy had been well unt three months before admission, when an infection of the upper respiratory tract had developed, and a coug which persisted Although he had not been weighed, his mother thought that he had lost some weight ar that he "wasn't walking right"

Physical examination showed a somewhat undernourished, pale, blond boy, who was lying in bed in r apparent pain or discomfort A marked apical thrust was palpated, 7 centimeters to the left of the mid lir at the fourth interspace There was no thrill or arrhythmia Following exercise, the pulse rate greatly ir creased and did not return to normal for some time At orthopaedic examination, bilateral genu valgum wa observed The patient walked as though both hips were stiff There was an increase in lumbar lordosis, ar both greater trochanters seemed slightly elevated The left thigh was 1 centimeter smaller than the righ in circumference The right lower extremity was 1 2 centimeters shorter than the left Motion at the hip was as follows flexion, 120 degrees on each side, abduction, 15 degrees on each side, adduction, normal c each side, external rotation—left 5 degrees, right 5 to 10 degrees, internal rotation, 0 degrees on each sid extension—left 0 to 5 degrees, right 5 to 10 degrees

At the time of admission the urine contained albumin (+++), leukocytes, and hyaline casts, weekl determinations for twenty-two weeks demonstrated no change The red-blood-cell count was 3,250,000 the hemoglobin was 65 per cent , the white-blood-cell count was 7,400 Serological findings were negativ The non-protein nitrogen at the time of admission was 146 milligrams and the creatinine was 4 3 milligram per 100 cubic centimeters

Roentgenograms of the left hip showed nearly complete destruction of the head of the femur, shortenin of the neck, increase of the joint space, and coxa vara The right hip demonstrated a slipped epiphy i widening of the neck of the femur, and destructive changes at the epiphyseal plate (Figs 2 and 3) Th diagnoses were Legg-Perthes disease of the left hip, slipped epiphysis of the right hip, and chronic glomeru lonephritis

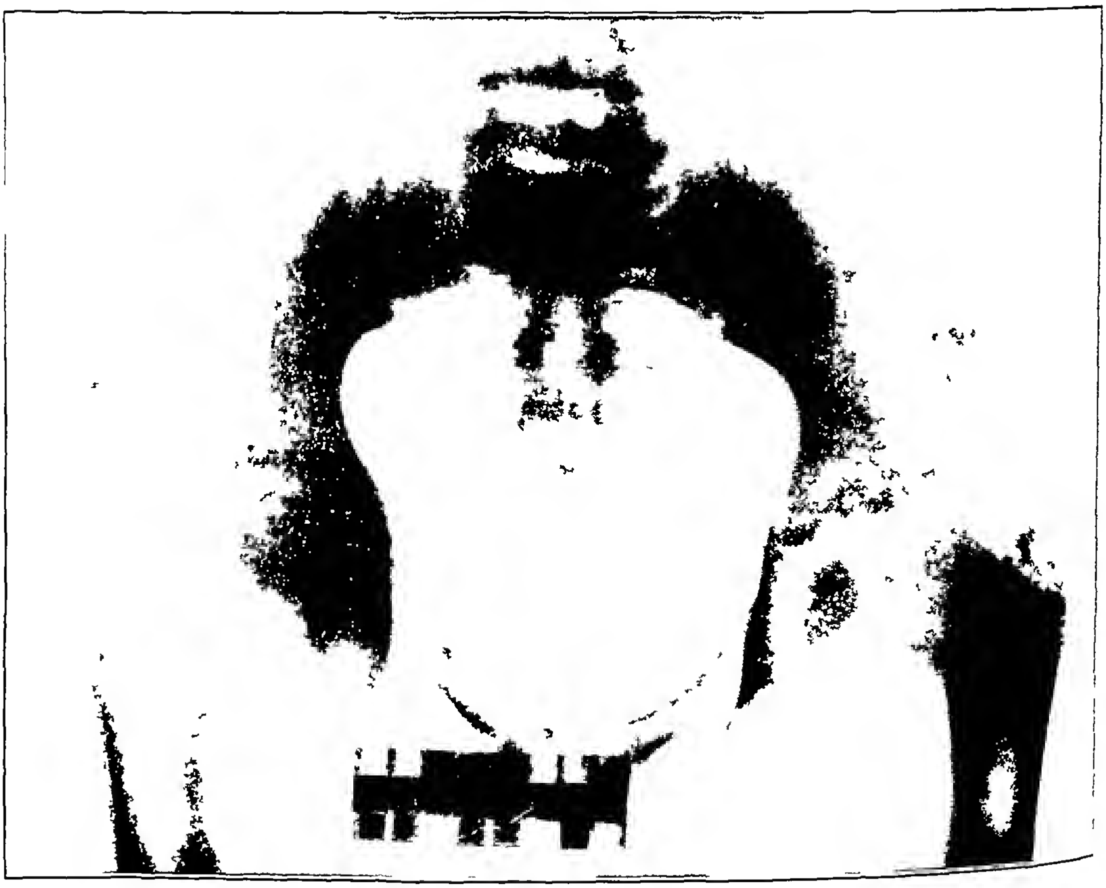

Fig 4

Roentgenogram taken three years after Fig 1

While the boy was in the Hospital, both lower extremities were placed in skin traction for two mont After removal of the traction, the limb lengths were equal Abduction and internal rotation were mark restricted bilaterally, yet the patient seemed to be able to walk much better He was afebrile during hi f and one-half months in the Hospital, and the non-protein nitrogen dropped to 82 milligrams per 100 cu centimeters He was discharged on June 22, 1937 (Fig. 4)

FRACTURES OF THE ANKYLOSED SPINE

BY ERNST W. BERGMANN, M.D., NEW YORK, N.Y.

From the Orthopaedic Service of Bellevue Hospital, New York City*

Fractures of the vertebral column in Marie-Strümpell disease are uncommon, yet in recent years a number of such cases have been seen by members of this Staff, some on this Service and some elsewhere.

Very little has appeared on this subject in the literature; all the author has been able to find are two single case reports from the German literature,—one by Abdi[1], in 1903, and the other, by Stiasny[2], in 1933. The first referred to a fracture of the lumbar spine in which the cauda equina was crushed, and the next to a fracture between the fifth and sixth cervical vertebrae, remarkable by the absence of gross neurological changes and also by its speedy consolidation.

To these we can add four cases of fracture through the lower cervical segments. A fifth case of this type is not included, as the patient died shortly after he was admitted to this Hospital. Although no definite conclusions can be drawn from this small number, the cases have much in common. They all occurred in middle-aged men with a long history of ankylosis of the spine, complete from the occiput to the pelvis. This completeness of bony fusion over the entire spine appears to be a pertinent factor in the fracture mechanism, as

FIG. 1-A

FIG. 1-B

Fig. 1-A: Case 1. A recent fracture through the interspace between the fifth and sixth cervical vertebrae.
Fig. 1-B: The fracture has consolidated.

the absence of any spring action within the spine makes it impossible for the impact of a fall to be absorbed.

Unlike a fracture of the compression type in the ordinary spine, the ankylosed spine breaks like a long bone, transversely, as a result of a bending force. All the fractures oc-

* Arthur Krida, M.D., Director.

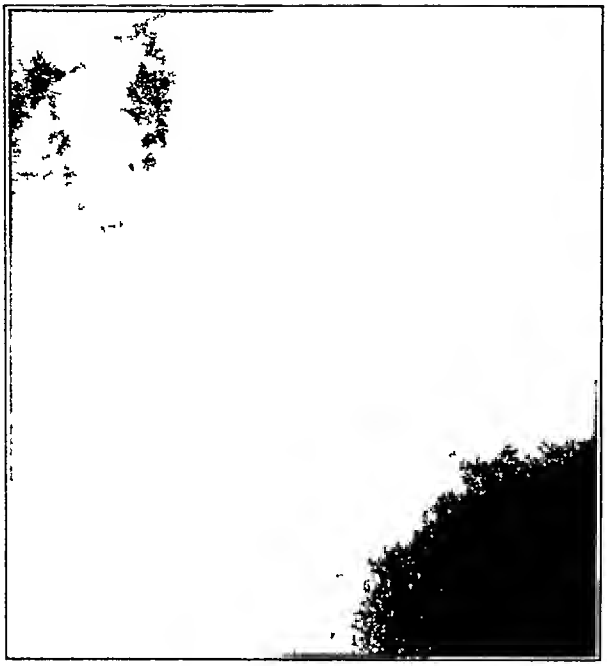

Fig. 2-A

Fig. 2-B

Fig. 2-A. Case 2. A recent fracture, at the same level as in Case 1.
Fig. 2-B. After healing of the fracture.

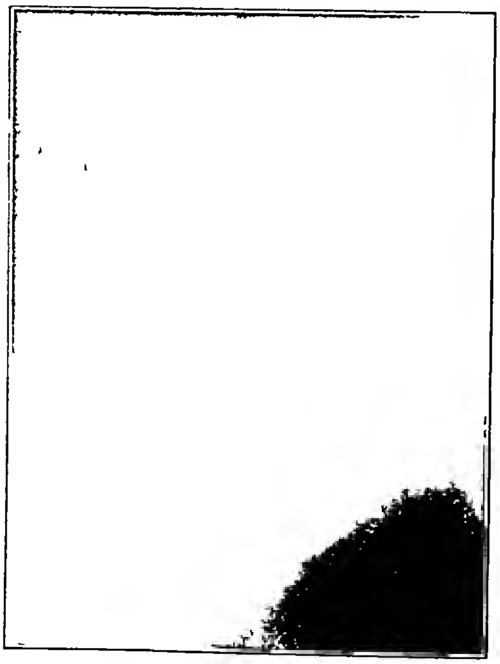

Fig. 3-A

Fig. 3-B

Fig. 3-A. Case 3. A recent fracture, at the same level as in Cases 1 and 2.
Fig. 3-B. After healing of the fracture.

curred through what had formerly been the interspace, rather than through the substan[ce] of the body itself. Most of them were at the level of the interspace between the fifth an[d] sixth cervical vertebrae. The time necessary for bony consolidation was uniformly sho[rt], the underlying tendency toward ankylosis obviously being responsible. The amount [of] cord or root involvement was in no way related to the degree of anatomical displaceme[nt] seen in the roentgenogram. However, the roentgenograms taken in the hospital do n[ot] necessarily represent the situation which existed at the moment of injury.

Although such a fracture is a serious injury, it may afford an opportunity to attem[pt] a certain degree of correction of the flexed attitude of the head, in order to improve t[he] range of vision. Conservative treatment in the form of head traction in a Sayre halter i[n]

several weeks followed by the wearing of a plaster collar, has proved adequate The amount of traction and particularly the direction in which it is exerted, has to be applied with great care for the individual patient

CASE 1 The fracture occurred when the patient was struck by a taxicab The exact mechanism of his fall could not be established, as he was intoxicated and confused at the time of admission From the displacement which was present (Fig 1-A), it would appear that he landed on his back and that his head, following the momentum, snapped backward Despite the pronounced anatomical separation with wide anterior opening of the fifth interspace, neurological symptoms remained negligible

After three weeks in a Sayre halter, the neck was sufficiently stable to permit the application of a plaster collar This was taken off six weeks later, at which time the roentgenogram revealed firm bony consolidation (Fig 1-B) It also showed the head in a slightly more extended position than prior to the injury, a fact which was borne out by the patient's statement that his range of vision had increased

CASE 2 (Observed by Dr Kinda) This man fractured his spine by slipping in the bath tub and hitting his head on the tub As a result, the upper fragment was in a slightly more flexed attitude (Fig 2-A) than before the injury Here, again, symptoms referable to the nervous system remained insignificant The roentgenogram of the healed fracture (Fig 2-B) showed the neck definitely more extended, with consequent improvement of the range of vision

CASE 3 (Observed by Dr E Blumenfeld) In this case the patient, while intoxicated, fell and struck the shoulder region against the ground, his head snapping backward The first roentgenogram (Fig 3-A) showed perhaps the slightest degree of displacement, yet he had immediate loss of power in all four extremities Any change in position of the head would lead to cessation of respiration, only when the head was placed in its original degree of flexion was respiration resumed Complete recovery from neurological symptoms, as well as bony union, occurred within six weeks (Fig 3-B) The position of the head and the range of vision remained unimproved

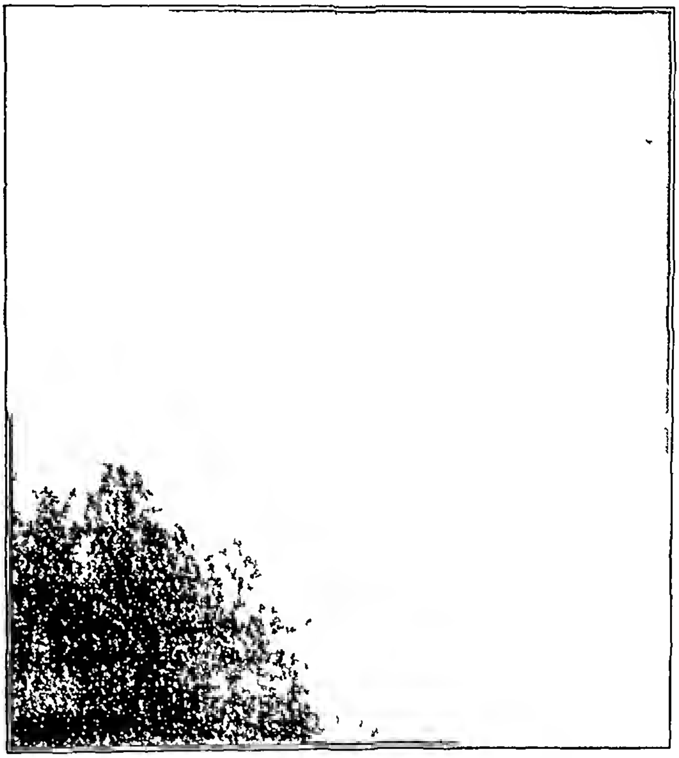

FIG 4

Case 4 Healed fracture through the interspace between the sixth and seventh cervical vertebrae

CASE 4 This man fractured his neck by falling down a flight of stairs, the head being pushed toward the chest He did not enter the Hospital until about one month later, so that no roentgenogram was taken immediately after the injury He was placed in a Sayre halter with the result that an existing paraesthesia of three fingers of the left hand promptly disappeared The roentgenographic picture after seven weeks (Fig 4) showed a healed fracture through the sixth interspace The patient stated that his neck was not quite so flexed as before, and that he could look straight ahead with less effort

In three of the four cases, some correction of the flexed attitude of the head was obtained, with corresponding improvement of vision The healing of the fracture itself was extraordinary, almost rapid In each case the neurological symptoms cleared up entirely or became insignificant

1 ABDI, O H Ueber einen Fall von chronischer Arthritis ankylopoetica der Wirbelsaule Fractur der Wirbelsaule und Quetschung der Cauda equina Mitt a d Hamburgischen Staatskrankenanstalten, 4 57–75, 1904

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TRIGGER THUMB IN INFANTS

BY EDWIN E. SPRECHER, M.D., SEATTLE, WASHINGTON

Few cases of trigger thumb are reported in the American literature. As a result many physicians are not familiar with the condition and it is often misdiagnosed. In 1930, Jahss reported ten cases, in all of which operation was carried out. He believed that the only treatment for this lesion is surgical. In 1940, Beck reported six cases. In his opinion this is a degenerative lesion which can be cured by splinting. Zadek, in 1942, reported two cases, both of which were cured by operation. He believed that the lesion is congenital. Rose, in 1946, reported two cases in which the disability was bilateral. He stated that the etiological factor is similar to that of de Quervain's disease, and that in these cases an audible snap may be produced.

Twelve cases with adequate follow-up examinations, which form the basis of this report, have been selected from a series treated at the Orthopaedic Hospital in Los Angeles.

The usual history of trigger thumb in infants is that the mother has noticed that the thumb cannot be completely extended. It may be extended easily to about 150 degrees; further effort causes the thumb to jerk before extension is complete. The thumb can be flexed about 30 degrees; it will then jerk before flexion can be continued freely during the rest of the excursion. After these symptoms have been present for several months, the thumb locks and can no longer be extended beyond 150 degrees. Active and passive motion throughout the rest of the arc of motion remain free. Often the "locking" or inability to extend the thumb completely is the first recognized symptom. Although some writers state that there is an audible snap, we have not observed this sign and have had no patients who included this in the history.

There is no history of trauma, and the child apparently has no pain. In all of these patients, symptoms appeared before the age of three years, and in four patients, locking of the thumb was noticed immediately after birth.

PHYSICAL EXAMINATION

Examination reveals a small, non-tender, palpable mass on the flexor surface of the thumb, over the neck of the metacarpal. As the thumb is moved, the mass moves up and down with the flexor tendon. The snapping is the only other abnormal finding. In three of the cases, the condition was bilateral; in two other cases, nodules were palpable in the opposite thumb, although there were no symptoms on this side. In five patients the symptoms were in the right thumb; in four, in the left. In three patients the first symptom noted was snapping of the thumb. In the remaining nine, the first symptom was that the thumb had locked in flexion.

MECHANISM OF INJURY

The tendon of the flexor pollicis longus is found to have a diffuse enlargement and the tendon sheath a constricted area at the level of the metacarpal head. The thumb can be extended until the enlarged portion of the tendon comes in contact with the constricted portion of the sheath. Further extension causes a jerking, as the enlarged area of the tendon slips through the constricted sheath. In certain stages of the ailment, the mass can be made to slip through the constricted area passively when the force required is so great that it cannot be done actively. When locking occurs, the nodule is always on the proximal side of the constricted area. The flexor muscles are stronger than the extensors and can pull the nodule through when the extensors are no longer able to do so. Since the nodule is on the tendon of the flexor pollicis longus which is attached to the distal phalanx, only the distal joint is involved in the process. Neither flexion nor extension is disturbed at the metacarpophalangeal joint.

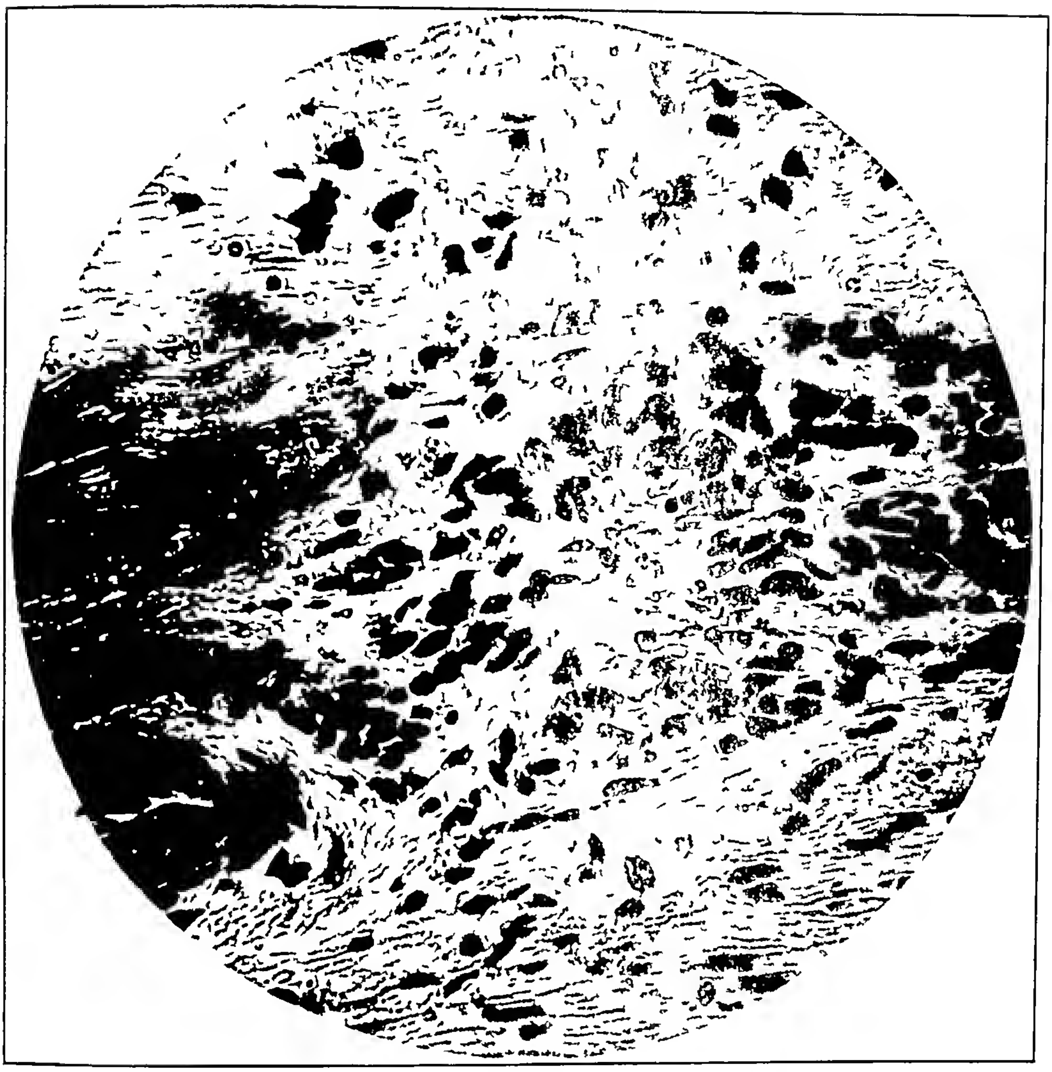

Fig 1
Photomicrograph of a section of tissue taken from the nodule in the tendon

ETIOLOGY

Since de Quervain's original report in 1895, numerous articles have been written on stenosing tenosynovitis, either at the radial styloid or involving the flexor tendons of the fingers It is agreed that the etiology in these cases is trauma Because the findings in snapping thumb in infants are the same, it is logical to conclude that the etiological factor is the same

It has been suggested that, because the condition is sometimes present at birth, it is of hereditary origin There is nothing in the development of the embryo which renders this area susceptible to the development of an abnormality Sections of the tendon show evidence of trauma A great number of lymphocytes and monocytes are present in the stroma of the tendon There is no evidence of bacterial invasion, and the large number of cells suggests a traumatic process rather than a hereditary one Anyone who has observed an infant has noticed that much of the time the fingers are closed over the thumb, keeping it in sharp flexion The tendon sheath has a normal thickening and constriction in this area, which act as a pulley It is conceivable that keeping the tendon sharply kinked over the pulley produces sufficient trauma to cause the lesion Since infants hold the hand in this position immediately following birth, it is possible that they do so before birth, also, if so, a traumatic process may be established by the time the infant is born It might be argued that this apparently minor trauma would not cause such a lesion, but in many cases of trigger finger in adults no specific trauma can be cited The cause must be ascribed to the

trauma under the heading of "wear and tear" Certainly this is no more severe than a continual kinking over the pulley

PATHOLOGICAL FINDINGS

The pathological findings are similar to those found in trigger finger in adults The pulley is thickened and constricted There is no excess fluid in the sheath, and the tendon slides freely in the sheath There are no adhesions between the tendon and the sheath, and no evidence of infection is present The tendon has a fusiform enlargement which has the appearance of normal tendon tissue When an incision is made into the enlargement, the tissue cannot be distinguished grossly from the adjacent tendon In the literature, only one instance was found where a biopsy had been taken of the nodule A microscopic section of the nodule taken from Case 11 in this series shows normal tendon tissue, infiltrated with lymphocytes and monocytes The general appearance is consistent with traumatic inflammation

TREATMENT

Some of these patients had an initial period of conservative treatment, but this proved unsatisfactory and surgery was resorted to in all cases The ages at the time of operation ranged from eight months to six years, the average age was twenty-nine months The oldest patient was thirty-four months at the time symptoms were first noted, in four patients the symptoms were noted at birth The average age was twelve and one-half months

Treatment for this condition is incision of the pulley Although some authors state that immobilization of the thumb will give satisfactory results, we cannot agree Even in one case in which the symptoms disappeared, the original condition returned soon after removal of the splint When one is not familiar with the lesion, the usual procedure is to expose the distal joint, but this is not desirable

In all cases the sheath was incised In two cases a portion of the nodule was removed as advocated by some authors, and in the remaining ten the nodule was left intact We do not recommend removal of the nodule, since in no case in which the sheath alone was split was there a return of symptoms

Method A small transverse incision is made, one-eighth of an inch distal to the proximal flexion crease of the thumb The incision is placed distally, because there is no subcutaneous tissue in the crease itself and the scar would, therefore, become more adherent The incision is placed on the volar and lateral surfaces of the thumb to avoid the sensory nerve to the lateral aspect, since at this level the sensory nerve is almost directly over the flexor surface The sheath is split near the base on one side If it is split in the center, scar tissue will be produced at the point of maximum friction The wound is closed by suturing the skin only No immobilization is necessary

RESULTS

The longest follow-up period was seven and one-half years, the shortest was n months The average follow-up for the twelve cases was twenty-six months Good results were obtained in all of the patients, and there were no complications In no case was there any lack of motion or strength, or any symptoms of discomfort

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ANDRY AND THE *ORTHOPAEDIA* *

BY R. BEVERLY RANEY, M.D., DURHAM, NORTH CAROLINA

I want you to picture an old man writing a book. He is eighty-three. The place is Paris, where he is Professor of Medicine in the Royal College and former Dean of the Faculty of Physick. The time is 1741,—fifty years before the French Revolution and a century before the discovery of ether anaesthesia. Our author's face, we can imagine, shows the scars of time and many a bitter professional battle. His eyes, however, are still bright with originality as he writes an opening paragraph and creates a new tool of thought (Fig. 1): "As to the Title, I have formed it of two Greek Words, viz. *Orthos*, which signifies streight, free from Deformity, and *Paidion*, a Child. Out of these two Words I have compounded that of *Orthopaedia*, to express in one Term the Design I propose, which is to teach the different Methods of preventing and correcting the Deformities of Children."[3]

L

Explication du titre d'Orthopédie

Quant au titre en question, je l'ai formé de deux mots grecs, sçavoir, d'*Orthos* qui veut dire *droit, exempt de difformité, qui est selon la rectitude*, & de *Paidion*, qui signifie *Enfant*. J'ai composé de ces deux mots, celui d'*Orthopédie*, pour exprimer en un seul terme, le dessein que je me propose, qui est d'enseigner divers moyens de prévenir & de corriger dans les enfans, les difformités du corps. L'expression m'a paru d'autant plus permise, que les deux célébres Auteurs que je viens de citer, en ont employé de semblables, le premier en donnant le titre de *Pédotrophie* à un Traité sur la *maniere de nourrir les Enfans à la mammelle*, & le second, celui de *Callipedie* à un Traité sur les *moyens d'avoir de beaux Enfans*. Deux titres qui sont tirés tout de même, du grec, le premier de *Pais* Enfant, & de *Trophe* nourriture, & le second de *Kalos* Beau, & de *Paidion* Enfant.

I

Explication of the Title of Orthopædia

As to the Title, I have formed it of two Greek Words, *viz.* Ὀρθὸς, which signifies streight, free from Deformity, and Παιδίον, a Child. Out of these two Words I have compounded that of *Orthopædia*, to express in one Term the Design I propose, which is to teach the different Methods of preventing and correcting the Deformities of Children. The Expression seemed to me the more allowable, that the two celebrated Authors above cited, have made use of Terms of the same Kind, the first in giving the Title of *Pædotrophia* to a Treatise upon the Manner of suckling Infants, and the second that of *Callipædia*, to a Poem upon the Method of getting beautiful Children: both which Titles are likewise taken from the Greek, the first from Παῖς an Infant, and Τροφὴ Nourishment, and the second from Καλὸς beautiful, and Παιδίον a Child.

FIG. 1

Andry's creation of the term *Orthopédie*.

The word "orthopaedics," like its creator, has had adversaries and has outlived them. "Orthosomatics", "orthontropia", the "orthomorphia" of Delpech and the "orthopraxy" of Heather Bigg are now strange even to medical ears. To the term "orthopaedics" has come gradually increasing acceptance, tempered always with a realization that the subject has far outgrown the literal meaning of its title. A century after Andry, Valentine Mott

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 26, 1949.

L'ORTHOPEDIE
OU
L'ART
DE PREVENIR ET DE CORRIGER
DANS LES ENFANS,
LES DIFFORMITÉS DU CORPS.
LE TOUT PAR DES MOYENS A LA PORTÉE
des Peres & des Meres, & de toutes les
Personnes qui ont des Enfans à elever.
PAR M ANDRY, CONSEILLER DU ROY,
Lecteur & Professeur en Medecine au College Royal,
Docteur-Regent, & ancien Doyen de la Faculte de
Medecine de Paris, &c
Avec Figures.
TOME PREMIER.

A PARIS, RUE SAINT JACQUES
Chez La Veuve ALIX, au-dessus de la rue des Noyers, au Griffon.
LAMBERT & DURAND, à la Sagesse, & à Saint Landry
M. DCC XLI.
AVEC APPROBATIONS ET PRIVILEGE DU ROY.

ORTHOPÆDIA:
Or, the ART of
CORRECTING and PREVENTING
DEFORMITIES
IN
CHILDREN:
By such MEANS, as may easily be put in
Practice by PARENTS themselves, and
all such as are employed in Educating
CHILDREN
To which is added,
A DEFENCE of the ORTHOPÆDIA,
by way of SUPPLEMENT, by the AUTHOR

Translated from
The *French* of M *ANDRY,*
Professor of Medicine in the ROYAL COL-
LEGE, and Senior Dean of the Faculty of
PHYSICK at *Paris.*
IN TWO VOLUMES
Illustrated with CUTS
VOL I
LONDON
Printed for A MILLAR, at *Buchanan's Head,* oppo
site to *Catharine street,* in the *Strand.*
M.DCC XLIII.

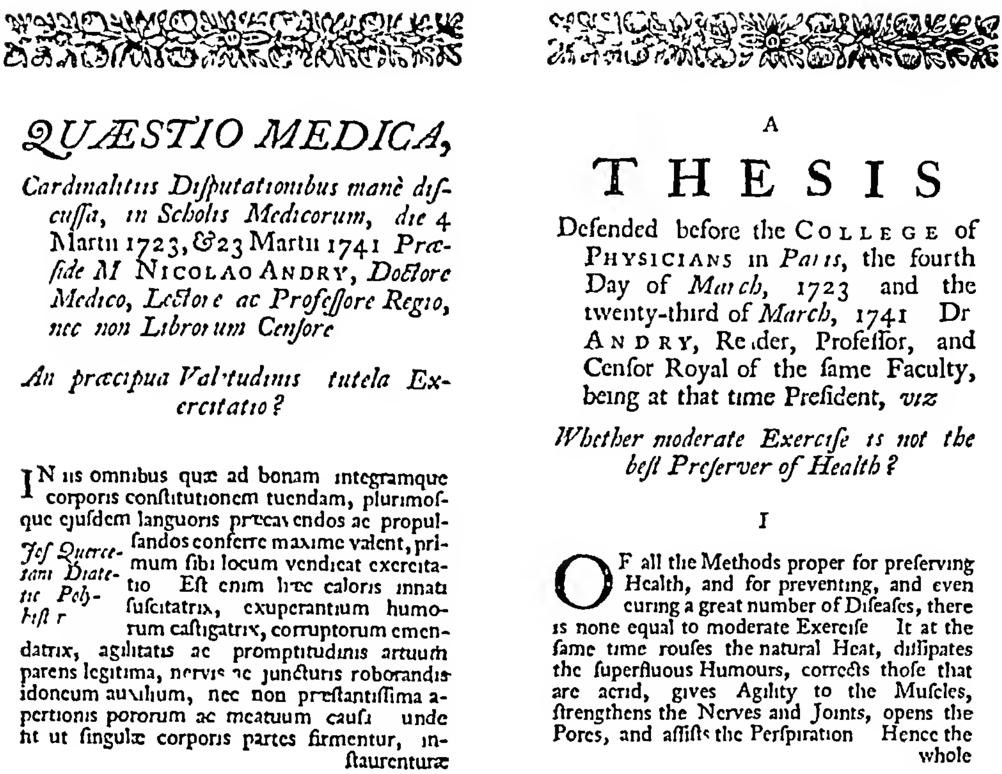
FIG 2
Title pages of French and English editions of the *Orthopaedia*

referred to "that beautiful and exact science *limitedly* denominated Orthopoedic Sur gery" Two centuries after Andry, Royal Whitman wrote "The ancient, ambiguous bu irreplaceable term 'orthopaedic', which for those who accepted its restrictions was an insuperable obstacle to progress, is now generally understood as indicating only a sphere of action' The meaning and the influence of orthopaedic surgery must continue to grow It is up to us to see that its standards remain high and that its further development, like that of Andry's children, is straight and healthy

The original, Paris edition of the *Orthopaedia* [2] was published in two duodecimo vol umes in 1741 Its title page (Fig 2) includes a reference to the sanction of the king The English edition [3] is an anonymous translation which was published in London in 1743 A Belgian edition appeared in 1742, and German editions in 1744 and 1762 The English volumes include, as mentioned on the title page, a translation of Andry's *Suite d'Ortho-pédie,* a spirited rebuttal of criticisms leveled at the *Orthopaedia* Both Paris and London editions include Andry's thesis on the virtues of exercise (Fig 3), which is entitled "Whether moderate Exercise is not the best Preserver of Health?"

Both French and English editions are illustrated by fifteen pages of copper-plat engravings An example (Fig 4) contrasts proper and faulty sitting posture in reading The frontispiece (Fig 5) is an allegorical drawing of children, mother, and orthopaed doctrine Most celebrated of the illustrations, however, is that of the splinted tree (Fig 6 which has gained wide recognition as a symbol of orthopaedic endeavor

The text of the *Orthopaedia,* divided into four books (Fig 7), describes the part (the body, classifies the deformities of children, analyzes causes, and presents method (prevention and treatment Andry writes in a natural, wholesome, vivid style Samp subtitles are "The Body like the Back of a Spoon" and "The Method of preventir



QUÆSTIO MEDICA,

Cardinalitiis Disputationibus manè discussa, in Scholis Medicorum, die 4 Martii 1723, & 23 Martii 1741 Præside M NICOLAO ANDRY, *Doctore Medico, Lectore ac Professore Regio, nec non Librorum Censore*

An præcipua Valetudinis tutela Exercitatio?

IN iis omnibus quæ ad bonam integramque corporis constitutionem tuendam, plurimosque ejusdem languoris præcavendos ac propulsandos conferre maxime valent, primum sibi locum vendicat exercitatio Est enim hæc caloris innati suscitatrix, exuperantium humorum castigatrix, corruptorum emendatrix, agilitatis ac promptitudinis artuum parens legitima, nervis ac juncturis roborandis idoneum auxilium, nec non præstantissima apertionis pororum ac meatuum causa unde fit ut singulæ corporis partes firmentur, instaurenturæ

Jos Quercetani Diætet Polyhist r

A

THESIS

Defended before the COLLEGE of PHYSICIANS in *Paris*, the fourth Day of *March*, 1723 and the twenty-third of *March*, 1741 Dr ANDRY, Reader, Professor, and Censor Royal of the same Faculty, being at that time President, *viz*

Whether moderate Exercise is not the best Preserver of Health?

I

OF all the Methods proper for preserving Health, and for preventing, and even curing a great number of Diseases, there is none equal to moderate Exercise It at the same time rouses the natural Heat, dissipates the superfluous Humours, corrects those that are acrid, gives Agility to the Muscles, strengthens the Nerves and Joints, opens the Pores, and assists the Perspiration Hence the whole

FIG 3

Title page of Andry's thesis on the value of exercise (English edition)

Children from pushing out the Backside too much" The fourth book (Fig 8), which deals with deformities of the head and even disorders of the complexion and defects of the voice, has been criticized widely as having nothing to do with orthopaedics Andry, however, doubtless interpreted deformity as including disfigurement It must be remembered that Andry was not writing primarily a scientific treatise, but a guide for the raising of healthy children As Kirmsse has pointed out, the pioneer of a new subject is likely to give either too little or too much

A more valid indictment of the *Orthopaedia* is that many of the treatments which it advocates are extremely weak or quite valueless[4] We should expect little correction of deformity from the active exercise occasioned by awakening the patient each morning with cold water thrown in his face, nor can we second Andry's treatment of applying to sprains "a well roasted salt Herring"

Despite such defects, the *Orthopaedia* contains an astonishing store of pertinent information and deserves fully the approval which it has received It collects and correlates the various deformities of the external parts of the body It directs attention to the supervision demanded by the physical needs of children, demonstrates the harmful effects of improper body mechanics at rest and in motion, and specifies a preventive as well as a corrective therapy The basic importance of clinical observation of the patient is brought out, the superiority of early treatment to late is repeatedly stressed Andry calls attention to the value of gentle massage and to the need for repetition and patience in the use of corrective manipulations The importance of simple gymnastics, of exercising deficient muscles, and of prescribing active exercise rather than passive movement is clearly set forth Andry describes and recommends what we now refer to as muscle-setting exercises He considers psychological aspects of treatment and prescribes recreational therapy In one paragraph he deprecates the use of soft beds and pillows, in another he recommends raising one border of the shoes if "the Feet incline too much to one Side" In some instances overcorrection of deformity is advised For acute minor injuries the value of immediate immersion in cold water is mentioned There is even a reference to

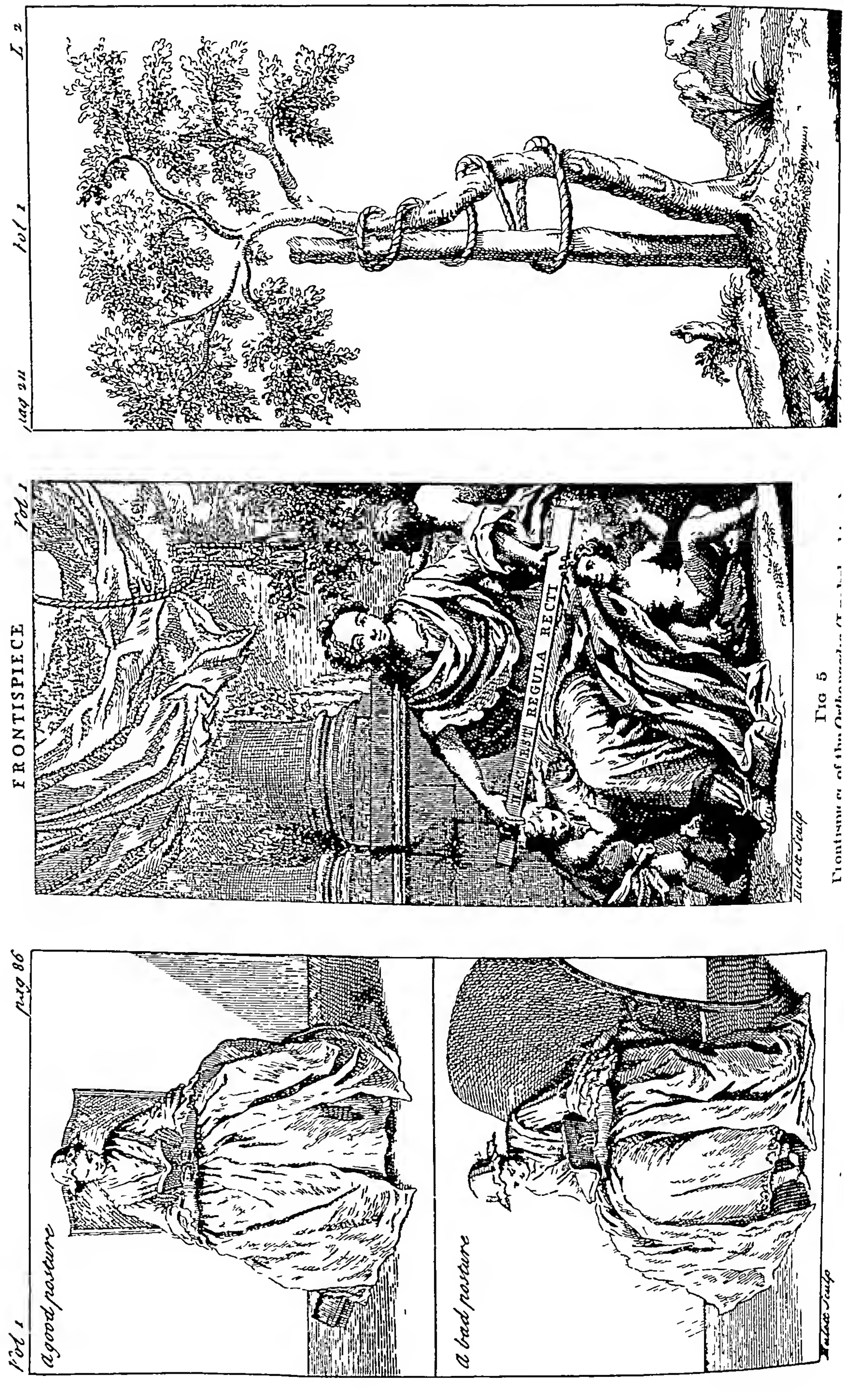
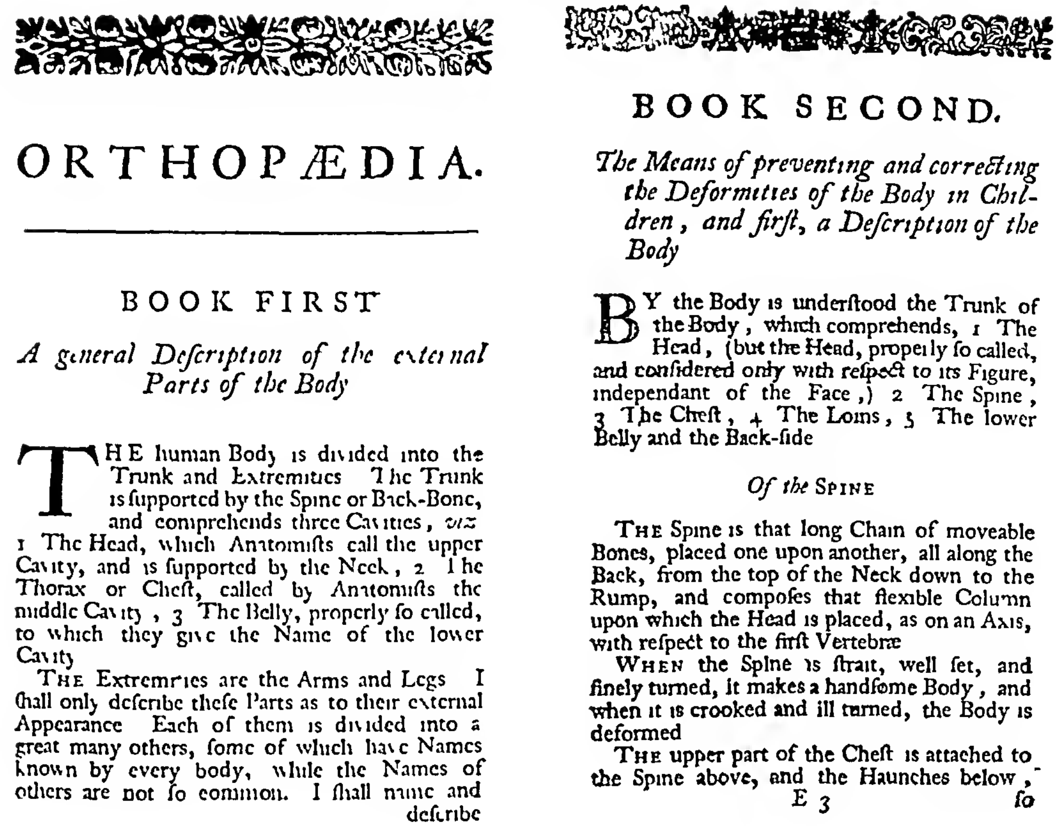


FIG 5

Frontispiece of the Orthopaedia (



ORTHOPÆDIA.

BOOK FIRST.

A general Deſcription of the external Parts of the Body.

THE human Body is divided into the Trunk and Extremities. The Trunk is ſupported by the Spine or Back-Bone, and comprehends three Cavities, *viz.* 1. The Head, which Anatomiſts call the upper Cavity, and is ſupported by the Neck, 2. The Thorax or Cheſt, called by Anatomiſts the middle Cavity, 3. The Belly, properly ſo called, to which they give the Name of the lower Cavity.

THE Extremities are the Arms and Legs. I ſhall only deſcribe theſe Parts as to their external Appearance. Each of them is divided into a great many others, ſome of which have Names known by every body, while the Names of others are not ſo common. I ſhall name and deſcribe

BOOK SECOND.

The Means of preventing and correcting the Deformities of the Body in Children, and firſt, a Deſcription of the Body.

BY the Body is underſtood the Trunk of the Body, which comprehends, 1 The Head, (but the Head, properly ſo called, and conſidered only with reſpect to its Figure, independant of the Face,) 2 The Spine, 3 The Cheſt, 4 The Loins, 5 The lower Belly and the Back-ſide.

Of the SPINE.

THE Spine is that long Chain of moveable Bones, placed one upon another, all along the Back, from the top of the Neck down to the Rump, and compoſes that flexible Column upon which the Head is placed, as on an Axis, with reſpect to the firſt Vertebræ.

WHEN the Spine is ſtrait, well ſet, and finely turned, it makes a handſome Body, and when it is crooked and ill turned, the Body is deformed.

THE upper part of the Cheſt is attached to the Spine above, and the Haunches below,

E 3 ſo

FIG. 7

Title pages of first and second books of the *Orthopaedia*

the ready healing of "porous and spongy" bone. The modern ring of many of these concepts is immediately apparent.

Andry's death one year after the publication of the *Orthopaedia* brought to a close an active life, filled with personal and professional strife. Nicolas Andry was born, the son of a poor merchant of Lyons, in 1658. He studied for the clergy, tutored to help meet expenses, and later became a professor of theology.[8, 13] His restless nature was unsuited, however, for the quiet life of the church; at the age of thirty-two he abandoned theology and undertook the study of medicine. He graduated at Reims in 1693, and was admitted to the Faculty of Medicine at Paris in 1697. He became a prolific writer of medical papers, discussing varied subjects including diseases of bone, diet, bleeding, purgation, and abstinence from liquor. Andry is said to have written the first description of infra-orbital neuralgia.[12] His book on worms[1], advancing the theory that each part of the body has its respective pathogenic worms, brought wide recognition; it also brought him considerable opposition and the nicknames *homo vermiculosus* and *homo verminosus*. Andry was sharply criticized for conniving with the apothecaries to sell his proprietary vermifuge. In addition to medical contributions, Andry wrote innumerable polemics and invectives. His criticisms of another author might well be applied to his own papers: "An ungoverned Heat prevails . . . it is not possible for more Passion to be discovered in writing."[3]

In 1712 Andry became Professor of Medicine at the College of France in Paris; twelve years later he was made Dean of the Faculty of Medicine. This office he filled for two memorable years in which his prodigious activity and turbulent spirit were fully displayed. Already he had had many contests with the surgeons, of whom Jean-Louis Petit, author of a famous treatise on injuries and diseases of bone, is perhaps the best known. On becoming Dean, Andry did everything in his power to see that the surgeons were shorn of their privileges and that the rights of the Faculty of Medicine were aug-

BOOK THIRD.

Deformities of the Arms, Hands, Legs and Feet.

1 *The* ARMS *too short or too long.*
2 *The* LEGS *too short or too long*

WE see some Persons who have both the Arms too short, or too long, and some that have one shorter or longer than the other We see them also with other Deformities of those Parts, as Knots, Crookedness, Distortions, &c The same is observed of the Hands, Legs and Feet. When they are born with those Defects, there is no Cure to be attempted, unless they are occasioned by some Violence which the Infant suffers from the Midwife

A FAMOUS King of *Persia* * had his right Hand longer than the left, and it was so long that he was surnamed *Longamanus* *Darius* and *Alexander*, as some Historians report, had their Arms so long, that they reached down to their Knees We oft enough see People who have their Arms so short, that they are obliged when they eat or drink, to bow down their Head to their Hands

As

* *Artaxerxes* the first, called *Artaxerxes Longamanus*

ORTHOPÆDIA.

BOOK FOURTH

The Deformities of the HEAD.

The Means of preventing and correcting those Deformities

THE Head, to repeat here what we said in the Beginning of the first Book, includes the Skull, the Hair, and the Face The Skull is the Case of the Brain, the Hair is the Covering of this Case, and the Face is a Composition of those Parts which compose the whole Fore-part of the Head Thus we have three Sorts of Deformities to speak of here First, those which affect the Head, with respect to the *Cranium*; secondly, those with respect to the Hair; thirdly, those with respect to the Face

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FIG 8
Title pages of third and fourth books of the *Orthopaedia*

mented Chereau [8] states that no other physician fought with such blind fury to prevent the surgeons from obtaining the honorable rank to which the nature of their profession entitled them Andry succeeded in obstructing the teaching of surgery by surgeons He managed to have passed a rule forbidding lithotomy unless a physician were present, and another prohibiting the publication of any medical work without the approval of the Faculty of Medicine Having disposed temporarily of the surgeons, Andry next engaged other members of the Faculty of Medicine in a struggle for power As his intrigues became known, his popularity dwindled, and in 1726 he lost the Deanship, despite his efforts to swing the election by summoning only those who he thought would vote for him

Of Andry's personal life we have little knowledge He was married three times, and had one daughter by his third wife He remained active professionally until his death in 1742, at the age of eighty-four years

It is strange that, despite a considerable volume of information on the life and personality of Andry, we know almost nothing of his physical characteristics and personal appearance No picture of Andry has been found at the College of Grassins, where he was Professor of Theology, or at the Church of Saint-Roch, where he was buried No picture has been found in his numerous works at the Library of the Faculty of Medicine in Paris although it was the custom of the period for the author's portrait to be used as a frontispiece It was also customary for each dean of the faculty of medicine to have his portrait engraved on a medallion, and, according to Mauclaire, reference to such a medallion has been found in a publication of 1858, nevertheless, the actual medallion has never been located In 1869, Chéreau [9] stated that a magnificent portrait of Andry was at that time displayed in one of the rooms of the Faculty of Medicine in Paris In 1937 Bonola [6] wrote that six fine portraits, which, judging from the large wigs, ermine capes, and black caps depicted men of Andry's time, had been located, but that their names and the dates had been lost during the Revolution and they had become known as "the Six Anonymous" Mauclaire believed that "Anonymous Number Three" (Fig 9) represented Andry

FIG 9

FIG 10

Fig 9 Portrait at the Faculty of Medicine in Paris, possibly representing Andry
Fig 10 Caricature of Andry attacking the shop of a barber-surgeon

Bonola[7] tells us that, in this portrait, François de Troy, one of the most famous portrait painters of the period, shows us a somewhat youthful and keen face with a full serene forehead, untouched by wrinkles, penetrating eyes, and a subtle ironic smile On the whole it is difficult to reconcile this picture with the age of Andry, which was eighty at the time at which the picture is dated, especially when Andry's life had been "a constant battle" There are other discrepancies, such as the absence of a Cavourian beard, the date of the painting—twelve years after Andry lost the deanship—and the fact that no mention of this portrait is made in catalogues of François de Troy's works These discrepancies have led Bonola to conclude that the portrait cannot be accepted without reservations

The only known pictorial representation of Andry is a caricature (Fig 10), which has been found at the Bibliothèque Nationale According to Delaunay, there were two variants of this etching Andry is represented in the act of trying to destroy the shop of a barber-surgeon by kicking at it and tearing down its sign He appears to be a slender man of moderate height, full of energy and anger

How are we to evaluate this colorful person? Of Andry's ability there is no question He is said to have been a man of great talents, sound knowledge, and brilliant imagination He has been described also as meddlesome, quarrelsome, abusive, jealous, full of low intrigues and mean passions, a grudger, and no amiable character It may be that, as suggested by Bonola[6], our information has been prejudiced by criticism emanating from Andry's wounded adversaries Apparent in every biography of Andry, however, is the striking combination of professional merit and personal disrepute

Andry's influence upon orthopaedic surgery is perhaps less difficult to assess He has been called the father of orthopaedics and the author of its first textbook, however, these designations apply only in so far as the term itself and the non-surgical orthopaedics of childhood are concerned As pointed out by Mercer, Andry "taught orthopaedics as a branch of preventive medicine, rather than as an off-shoot of surgery" Most apt is Putti's designation of Andry as the *vecchio padrino* (old godfather) of orthopaedics

It is important that, by his very attacks upon the surgeons of his day, Andry may have exerted a most constructive influence on the development of surgery and its specialties To appreciate this, we must realize that in Andry's time the standards of surgical education and practice were far inferior to those of medicine In France the battle between

qualified surgeons and their medical confreres, on the one hand, and the unedu barber-surgeons, on the other, had raged for more than a century In England an act separate qualified surgeons from barber-surgeons was passed by Parliament three ye after Andry's death[12], in France a decree reconciling physicians and surgeons was issu by the Convention in 1794[15]

Finally, to return from this glimpse of the past to our problems of today, what c modern orthopaedic surgeons learn from Andry? He would be the first to agree that, t better the surgeon, the less often he finds surgery necessary We have all become surgeo and debate techniques of treatment, how much more effective would be an increa knowledge of prevention We know how to reduce a fracture, but not what makes it hea how badly we need a pioneering imagination in research! The greatest lesson from Andr is to preserve for our beliefs and practices his spirit of sharp questioning and critici Only thus can we hope to separate truth from fallacy, keep our house in order, and co tribute to the further growth of orthopaedic surgery

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REPORTS OF THE VISIT TO GREAT BRITAIN OF ORTHOPAEDIC SURGEONS FROM THE UNITED STATES AND CANADA

On March 17 our group of fifteen sailed from New York on the Queen Mary. There were ten Americans: L. Ramsay Straub of New York, J. Hamilton Allan of Philadelphia, Carroll B. Larson of Boston, Hugh Smith of Memphis, Benjamin E. Obletz of Buffalo, John J. Fahey of Chicago, S. Benjamin Fowler of Nashville, William H. Bickel of Rochester, Minnesota, Verne T. Inman of San Francisco, and Donald W. Blanche of Los Angeles. There were also five Canadians: Frank Patterson of Vancouver, William B. MacKinnon of Winnipeg, F. P. Dewar of Toronto, Roger Gariepy, and Leo Walker of Montreal. The crossing was made with clear weather and on a calm sea.

When the ship docked at Southampton, we expected someone to meet us, but were astonished to be greeted by a group of five members of The British Orthopaedic Association, who came aboard, had dinner with us, and then, through a prearranged plan, got us off the ship and through customs in the least possible time. We were then escorted by train to London and to the Cumberland Hotel.

The next evening representatives of The British Orthopaedic Association gave a welcoming banquet. This initial reception proved to be typical of the planning and hospitality that was in store for us on the entire trip.

We stayed in London the first week, visiting seven hospitals. At each hospital visited, a full and very interesting program had been planned, with subjects presented by various members of the orthopaedic staff, often with the cooperation of the departments of medicine, general surgery, x-ray, and pathology. The surgeon presenting a subject had it well prepared and, in many instances, illustrated his points with ingenious models or diagrams, then showed patients. These were usually out-patients, many no longer under active treatment, who willingly came to the clinic at the request of their surgeon. We were impressed throughout the trip by the faith of the patients and gratitude shown for their surgeons.

Most of the hospitals are centuries old, with a rich historical background and with names familiar to us from the literature. It was most inspiring to walk in these halls through which so many great men have passed and in the libraries and museums to see the handwritten manuscripts and the pathological specimens prepared by them.

The old city of London was very severely damaged by bombing, and a great deal of this has not yet been cleared away. In the rest of London, the bomb damage is much less evident, but there are many vacant lots where buildings once stood, and many buildings which appear relatively normal from the outside are completely gutted within. Several of the hospitals had suffered from bombing. There is so much repair work to be done that there is relatively little new construction being carried on.

The remainder of the trip was made in a chartered bus in which we traveled the length and breadth of England, and into Scotland, a total of 2400 miles, visiting thirty-three hospitals and six rehabilitation centers. In the country districts, many of the hospitals are of simple one-story construction of large wards, one side being entirely open, or closed only by folding doors or curtains. In many, the beds are mounted on large wheels to facilitate moving into the open. The patients in these wards appeared particularly healthy and cheerful. Many of the hospitals have their own brace shops. The operating rooms are almost uniformly of ample size, and constructed for efficiency of use and of cleaning. There is a general shortage of hospital beds, and also a shortage of nurses, so that there is considerable delay in admission of elective cases to the hospitals. We were impressed by the ability of the orthopaedic nurses, who, after the completion of their regular training period, are given additional training in the care of the orthopaedic patient and are therefore invaluable, not only in the treatment of hospital patients, but also in working in distant diagnostic and follow-up clinics, and in making contacts with patients in their homes.

In general, the types of orthopaedic cases seen in the wards of the British hospitals were similar to our own, except that there was a much higher incidence of bone and joint tuberculosis. It is impossible to make sweeping statements concerning the surgical care and to compare it with our own, because, as in America, opinions and methods vary from hospital to hospital, or even from service to service within one hospital. It seemed to us that in general the treatment was similar to corresponding hospitals in our country, without a great deal of variance between the average British and average American center. In fact, it was when the various members of our group discussed a surgical problem that the widest diversity of opinion was expressed. There is a tendency to segregate cases in special centers, where, through study and experience, knowledge and skill can be obtained in treatment of this particular problem.

In a number of hospitals, hand injuries were segregated and this problem was placed under the supervision of one surgeon. The methods of tendon surgery were not essentially different from those commonly practised in this country, or in other parts of Britain, but it was in these special centers that the best results were seen, attributable to greater skill and experience.

Under the impetus of the recent War, centers were set up for treatment of peripheral-nerve injuries. At the onset, there were few surgeons in Britain trained or especially interested in this group of patients, and

their care gravitated to the orthopaedic surgeon Through the development of special centers, a great d has been learned and peripheral-nerve injuries have become generally recognized as within the scope of th orthopaedic surgeon Uniform standards for grading end-results have been agreed upon, so a more accura follow-up can be carried out and results appraised

Patients requiring amputations are sent to centers which are set up to provide complete care for surgery fitting of prostheses, and training in their use, with close cooperation between surgeon, limb fitter, and re habilitation counsellor After a patient has been fitted, he is trained in the use of the appliance, be it fo upper or lower extremity

Throughout Britain, much interest is being shown in the problem of the arthritic hip, with argumen between the proponents of arthrodesis and arthroplasty During our tour, approximately ten different typ of hip arthrodesis were presented, some intra-articular, some extra-articular, some combined, and with co siderable enthusiasm for metallic internal fixation In the same hospitals, Vitallium-mold arthroplasties we being done frequently, and we were shown some excellent results, although, in most instances, the patien were still in their recent postoperative period For the hip with intra-articular infection, such as tuberculo the ischiofemoral arthrodesis was found to be popular In most instances, this was performed through a sim ple lateral approach, although there seemed to be a growing tendency to operate through a posterior incisio under direct vision

In treatment of bone and joint tuberculosis, conservatism is the watchword It is believed that tuber culosis is a generalized disease and the local lesion is only one phase, therefore, the patient needs long sani tarium care at bed rest, no matter how the local lesion is treated Spine lesions are treated in recumbency on a Jones frame or a plaster bed until the lesion is quiescent (at least eighteen months in adults, and longer in children) The patient is then fitted with a brace and is allowed up It is believed that the spine will fuse spontaneously in most cases, and surgical fusion is necessary only in a small percentage In former year earlier fusion operations were done, but studies showed that the period of treatment was not shortened, and there were more complications Patients with paraplegia have in the past been treated conservatively, and still are, in some hospitals, although in most centers visited, surgical anterolateral decompression of the spinal cord through a costo-transversectomy approach is now advised, if the patient does not make rapid response under conservative treatment Patients with tuberculosis of the hip are generally treated with a long period of rest on a Jones frame or similar apparatus, then, after fibrous ankylosis has been secured, an extra articular fusion may be done The supply of streptomycin is so limited that its use is confined to the desperate case, such as tuberculous meningitis

Inequality of limb length in children is a rather frequent complication of tuberculosis and osteomyelitis This problem is solved in most instances by limb-lengthening procedures, and we saw some excellent results Shortening of the opposite extremity is rarely done, and we saw no instances of surgical epiphyseodesis

In fracture treatment in general, considerable emphasis is being placed on early function and minimum immobilization Spine fractures are common in the coal-mining districts In some mines, the seams are narrow and the ceilings so low that the miners work in a flexed position, thus they are particularly vulnerable to spine injuries in cave-ins Most surgeons adhere to the principle of reduction of simple compression frac tures by hyperextension followed by plaster-cast immobilization However, there is a strong belief in several centers that the simple compression fracture need not be reduced or immobilized, deformity of a vertebral body not being considered to be the cause of future disability They also believe that the hyperextended position is the cause of subsequent lumbosacral back pain, and immobilization the cause of joint stiffness

Fractures of the femoral shaft are almost uniformly treated in traction on a Thomas splint, unless satisfactory position cannot be obtained, or some other fracture is present, demanding open reduction Then in suitable cases, the Kuntscher nail is being used Fractures of the neck of the femur are universally treated by internal fixation, almost always with the three-flanged nail In the majority of the hospitals visited in ternal fixation of intertrochanteric fractures by means of a blade-plate is recommended when practicabl although, in some hospitals, traction is considered to be the treatment of choice

There was considerable interest manifested in fractures of the os calcis, and in several centers, ope reductions were being tried, and the results compared with those treated conservatively with no reduction o immobilization, but with early active exercise While the numbers of cases were small, the impression ob tained was that the appearance of the foot was better after surgery, but function was not improved, good functional results being obtained by either method

Patients with tentative diagnoses of rupture of a lumbar intervertebral disc are in most instances give a trial at conservative treatment of rest and immobilization Those who do not respond are operated on b the orthopaedic surgeon for removal of the disc, but in most instances a fusion is not done Contrast myelo raphy is not uniformly carried out as an adjunct to diagnosis

One other subject should be mentioned, — rehabilitation, which has received much more attention in England than in America In general, rehabilitation centers can be grouped into three types First, there is the type where the injured man is put back to productive work at the earliest possible time, while wearing dressing or cast There is a separate building on the factory grounds where regular production machines ma be adapted to the capability of the patient, and, as convalescence progresses, the hand grip or foot tread of the machine may be altered so as to give appropriate exercise to the injured part Almost any patient wi

is ambulatory is put to some type of work. Recovery is more rapid, periods of loss of work are greatly diminished, and the morale of the worker is enhanced by this procedure. This plan exemplifies a new social outlook. Management and labor work together closely, the individual assumes chief importance, and his work and place in society is not changed by his illness or injury.

The second type of rehabilitation center is for those patients who have been so severely injured that they will be unable to return to their former type of work, or for those congenitally handicapped persons who have never been able to work or support themselves. Here the individual is taught a trade by a skilled craftsman, whose goal is to train the cripple in both skill and speed so that he can compete successfully with the normal workman. The subtle training in mental and personal physical readjustment necessary to daily living is learned along with the vocational training, and it is for this phase principally that the resident school is preferable to the day school. For those individuals who are so severely crippled that they cannot compete on the open labor market, permanent residence and sheltered employment is provided, but here again the emphasis is on real production and self support, rather than on the custodial care so often doled out in this country.

The third type of rehabilitation center is set up principally to aid in recovery of such persons as miners who have had spine fractures or other injuries necessitating long periods of disability, and who need physical reconditioning before returning to work. In these, the emphasis is on gymnasium work, games, and outdoor physical labor.

The Spring Meeting of The British Orthopaedic Association came at the end of our first month in Britain. By this time we had become acquainted with many of the surgeons. One half day was spent at one of the large suburban hospitals where over a hundred out patients and many in patients were assembled for examination. There was a concise history and series of x-rays with each patient, so that the individual surgeon could examine and study them at will. At the scientific meetings, one was impressed by the very able presentations, almost all talks being given without any reference to notes. Four of our group were invited to present papers.

At the various centers visited, the local surgeons met us for a social evening, often in their own homes. Everyone was most hospitable and spared no effort to entertain us and make us feel welcome. It was at these informal gatherings that we learned much of the ordinary customs and opinions of the British people, and could discuss various medical problems. At every center we were honored by a banquet, attended by all of the local orthopaedic surgeons, and many of the hospital consultants representing other specialties. Many of the districts visited were interesting historically, and after the day's hospital rounds had been finished, we visited castles, cathedrals, country churchyards, beautiful gardens, and historical monuments.

In Scotland we each obtained a tartan waistcoat of our own, or fancied, clan, and adopted them as the badge of our group, to be worn at future reunions.

All of the traveling orthopaedic surgeons from the United States and Canada were most grateful for the opportunity of visiting Great Britain. It is the hope of both our group and the British group who last year came to America, that reciprocal visits may continue in the future. We learned a great deal about the scientific aspect of orthopaedic surgery. We learned much of the historical background and culture of the British people, without which it is impossible to understand their philosophic and political outlook. We became acquainted with many British surgeons, which was perhaps most important of all, for it is through such friendships and understanding that medicine on both sides of the Atlantic will prosper.

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Being most enthusiastic about our visit to Great Britain, I wish to plead for other contemporary orthopaedic surgeons on both shores of the Atlantic, who have not yet had an opportunity equal to ours, that traveling group fellowships be continued as part of the educational program of our senior orthopaedic societies. I know that I speak with the wholehearted approval of all those who have shared in this exchange.

It is significant that the average age of the Fellows is approximately forty years. These men have completed their formal training, are firmly fixed on the paths of orthopaedic surgery, and will succeed to positions of increased responsibility and leadership in their own centers. That participation in such an exchange adds greatly to their knowledge and resources is undisputed, and it follows that their value to their centers will be augmented by this experience.

The dissemination of knowledge is difficult within our own borders and international transmission is doubly so. *The Journal of Bone and Joint Surgery*, this excellent intermediary, has done much to remedy the situation, but written words are no substitute for experience. The untraveled reader is always confronted with the impossibility of fitting the paper to its locale and to the personality of its author. The unknowing cannot advise wisely regarding overseas educational opportunity, nor do friendships spring easily from scientific treatises.

Strong mutual ties flourished during World War I with the advent of North American surgeons to hospitals in Britain. Friendships resulted, many of which are still vigorous, and until the present these have been the mainsprings of our common interests. The widespread battle fields of World War II, scattering the spe-

cialists, opposed the continuity of this tradition and many orthopaedic surgeons now destined to teach fi[nd] themselves limited in knowledge of their contemporaries overseas

Occasional visits of distinguished people, whose activities are necessarily limited to a very high level, and sporadic interchange of junior men in training will not develop the desired degree of international understanding Groups, traveling under the guardianship of the Orthopaedic Associations, present this potential, for it should be possible to enlist one man from each center of orthopaedic surgery Organized tours to the centers famous for their work have other advantages, they enable the host to recall many out patients, who would otherwise not be seen, for the purpose of demonstrating long-term end-results Discussion too, is enhanced, for the traveling group can usually supply one individual better versed than the remainder in the subject under debate, and this participation fosters respect and friendship among the group itself

Such a program is not feasible without the continued and enthusiastic support of all the senior orthopaedic surgeons in our three countries, who may take pride in their leadership With few exceptions, men of our age group could not afford a like journey in spite of the obvious advantages The first reciprocal exchange has been accomplished by the personal generosity of members of our Orthopaedic Associations, assisted by grants from the Nuffield Foundations, and we are most grateful It is hoped that other Foundations interested in postgraduate education will be stimulated by the success of this first venture to make possible further traveling group fellowships

F P Dewar, M D,
Toronto, Ontario, Canad[a]

ELLIS WILLIAM JONES

1884–1948

Orthopaedic surgery in the Southwest is relatively a new specialty In 1913, there were not more than two orthopaedic surgeons in Los Angeles, and none in the outlying communities Ellis Jones came into the field after a thorough training in Eastern Centers and in Europe A man of unlimited energy and enthusiasm, he threw himself into his chosen work An Orthopaedic Clinic was developed at the Children's Hospital and others in Santa Barbara and Long Beach Not only was care furnished to the needy, but interest in orthopaedic surgery was stimulated in young men by his teaching

Ellis William Jones was born in Wales, and shortly thereafter came to Virginia with his parents He received his education in Boston, graduating from Harvard University in 1906, and Harvard Medical School in 1910 After internships at Massachusetts General and Peter Bent Brigham Hospitals, and a Residency in Surgery at Waterbury Hospital in Connecticut, he became an assistant to the late Fred H Albee in New York After completing his training with Dr Albee, Dr Jones spent six months with Sir Robert Jones in Liverpool, who invited him to remain as an associate in practice

Dr Jones made many valuable contributions to medical literature, among them *The Operative Treatment of Irreducible Paralytic Dislocation of the Hip Joint, Synovectomy of the Knee Joint in Chronic Arthritis, Operative Treatment of Chronic Dislocation of the Peroneal Tendons*, and *Trochanteric Transplantation in the Treatment of Fractures of the Neck of the Femur*

In 1937, Dr Jones was a guest of the British Medical Association at Belfast, and presented a paper *Fracture of the Neck of the Femur*

He had a great interest in surgery of the knees and hips, and his work in this field was quite remarkable

Dr Jones was a member of many California Medical Associations, the American College of Surgeons, The American Orthopaedic Association, The American Academy of Orthopaedic Surgeons, The International Orthopaedic Society, American Medical Association, and the Cancer Research Association To all of these organizations, he contributed generously of his time and ability

Dr Jones was married February 28, 1914, to Elizabeth Bradley, who survives him, together with two sons, Dr Ellis Jones, Jr, of Pasadena, and Harvey Bradley Jones of Los Angeles, California

Dr Jones was a surgeon of unusual ability, a man of pleasing personality He attracted people and made friends in all walks of life His sincerity of purpose and interest in humanity provided many a hopeless cripple with the will to recover As he strides on down the corridor of time, his shadow will ever lengthen as his contributions to suffering humanity become more manifest

R. NELSON HATT

1889–1949

Dr. Rufe Nelson Hatt, aged fifty-nine, died of coronary thrombosis in his home, 2620 Anuenue Street, Honolulu, T. H., Friday morning, May 27, 1949. Able, genial, lovable, Nelson Hatt will be mourned by many and, not the least, by the young men and women who, as children, benefited by his skillful and kindly ministrations.

Born in West Paris, Maine, on November 11, 1889, he received his early education there, prepared for college at Bridgton Academy in Harrison, Maine, and was graduated from Colby College in 1914. Following his graduation from Tufts Medical School in 1918, he served his orthopaedic internship at the Massachusetts General Hospital in Boston. Continuing at the same hospital, he held the posts of Assistant in Orthopaedics and Assistant Surgeon to Out-Patients, at the same time carrying on an orthopaedic practice in Boston.

During his years at the Massachusetts General Hospital, he made such rapid strides in orthopaedic surgery that the man under whom he studied, Dr. Robert B. Osgood, strongly recommended his appointment as Surgeon-in-Charge of the Mobile Unit of a Shriners' Hospital for Crippled Children, then about to be established in Honolulu. Before accepting the post, Dr. Hatt visited the famous Scottish Rite Hospital for Crippled Children in Atlanta, Georgia, the model upon which the Shriners' Hospitals were patterned, where he was further inspired by the great work of Dr. Michael Hoke. He accepted the Honolulu post and assumed charge there in December 1922. He organized the Honolulu Unit at Queen's Hospital under great difficulties. His achievements in this field were so marked that, shortly before the completion of the New England Unit of the Shriners' Hospitals at Springfield, Massachusetts, he was recommended by the Shriners' National Advisory Board of Orthopaedic Surgeons as the man best suited to take charge of the Springfield Unit. He reluctantly left Honolulu in November 1924, after almost two years in the Hawaiian Islands, and, on December 24 of the same year, took charge of the nearly completed Springfield Shriners' Hospital.

In August 1942, Nelson Hatt entered the Army Medical Corps in World War II. He went overseas immediately following the invasion of Sicily in 1943 and was a front-line surgeon during the strenuous days of the first landings on the southern front of Europe. Due to a knee injury received in line of duty, he was returned to the United States in May 1944; he was assigned to the Thomas England General Hospital in Atlantic City as Chief of the Orthopaedic Service. Later he was stationed at the Cushing General Hospital in Framingham, Massachusetts, as Chief of Orthopaedic Surgery.

He had had a very difficult time making the decision to leave his work with the crippled children to serve with the Army, and his assurance that he had made the right decision came in a letter sent to a friend in Springfield, written while he was with the troops in Sicily.

> "I am getting a kick out of this service and I have long since ceased to wrestle with my conscience for having deserted one of the most important jobs on earth, a crippled child," he wrote. "Here I have an opportunity to send the Jones's kid or the Brown's only boy back alive or to save an arm or leg for Junior Smith. It may sound a bit strange, but the same service to Karl Heinrich or Guiseppe Biorni has been gratifying too."

After leaving the Army Medical Corps in 1946 with the rank of Lieutenant Colonel, Dr. Hatt returned to the post of Chief Surgeon of the Shriners' Hospital in Honolulu, which he had left when he accepted the position in Springfield in 1924. He continued to serve in this capacity until his death.

He was honored by his colleagues in the medical profession in Springfield with his election to the Presidency of the Springfield Academy of Medicine in 1939. The following year he was appointed by Governor Leverett Saltonstall to a five-year term as member of the Massachusetts Public Health Council. He was the recipient of the Pynchon medal, awarded annually in Springfield for outstanding service to the community. In 1938, at its commencement program, his Alma Mater, Colby College, presented him with an honorary degree of Master of Arts. He was a 32nd degree Mason, and was a member of the American Medical Association, The American Orthopaedic Association, The American Academy of Orthopaedic Surgeons, the Forum Orthopaedic Club, the American College of Surgeons, and the New England Surgical Society.

Among his contributions to literature are *The Central Bone Graft in Joint Arthrodesis*, *Some Orthopaedic Gleanings from a Neurosurgical Center*, etc. Two papers, *A Twenty-five Year Follow-up of Tuberculosis of the Spine* and *Observations on Muscle Transplantation in the Lower Extremity*, were in preparation at the time of his last illness.

He is survived by his wife, Dr. Ednah Swasey Hatt; a son, Dr. William Hatt, an intern in the Queen's Hospital, Honolulu; and two daughters, Mrs. Mary E. Box of Salem, Massachusetts, and Constance Hatt, a student at the Punahau School in Honolulu.

The memory of Nelson Hatt will remain indelibly inscribed in the minds of those who knew him or who have had the privilege of coming in contact with him. His fine fellowship was a boon to many an old and many a new friend. His service to every community in which he lived was not only gladly and graciously given, but was of lasting value. He led a full life, a genial one, and gave all he had each day. To quote Dryden as a fitting epitaph—

> "Happy the man, and happy he alone,
> He who can call today his own,
> He who, secure within, can say,
> Tomorrow, do thy worst, for I have lived today."

News Notes

The Seventeenth Annual Meeting of **The American Academy of Orthopaedic** Surgeons will held in New York City, February 11–16, 1950 Headquarters will be at the Waldorf-Astoria

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Dr Robert I Harris, of the University of Toronto, has been awarded Honorary Fellowship in the R College of Surgeons of England The Council made him Hunterian Professor, his Hunterian Lecture, livered on April 29, was on the subject "Spondylolisthesis"

In the list of new Fellows elected to **The American Academy of Orthopaedic Surgeons**, publi in the April issue of *The Journal*, the name of Dr Carmelo C Vitale of Brooklyn, New York, was i vertently omitted

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The Washington Orthopaedic Club, at its meeting on May 23, 1949, elected the following offi for the coming year President, Dr Milton C Cobey, Vice-President, Dr Thomas Foley, Secretary Tr urer, Dr Everett J Gordon

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Word has been received of the election of the following officers for the year 1949–1950 of the Socieda **Nacional de Cirugia** (Cuba) President, Dr José Lastra Camps, Vice-President, Dr Manuel Costal Latatu, Secretary, Dr René Smith, Vice-Secretary, Dr Luis Rodríguez Baz, Treasurer, Dr Anto Rodríguez Díaz, Vice-Treasurer, Dr Tomás Armstrong

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Announcement is made of the organization of the **Association of Bone and Joint Surgeons** Th organizational meeting was held in Oklahoma City, Oklahoma, April 1 and 2 Dr Earl D McBride of Okl homa City was chosen President for the first year, and Dr Fritz Teal of Lincoln, Nebraska, Secretary It expected that the meetings will be held annually, and that the organization will be national in scope Certi cation by The American Board of Orthopaedic Surgery is one of the requirements for membership

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The National Council of the **Kappa Delta Sorority** has inaugurated a prize of one thousand dollar to be given annually by **The American Academy of Orthopaedic Surgeons**, for the best research orthopaedic surgery, performed during the year by an individual in the United States The first award, f the year 1949, will be announced at the Seventeenth Annual Meeting of the Academy in New York, Feb ary 11, 1950 Those wishing to compete for this prize may secure further information from the Chairman the Award Committee for 1949, Dr Walter Stuck, 1426 Nix Professional Building, San Antonio, Texas

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The American Board of Orthopaedic Surgery, Inc, has announced new officers for the year 19.. as follows

President, Dr Allen F Voshell, Baltimore, Maryland,
Vice-President, Dr Ralph K Ghormley, Rochester, Minnesota,
Secretary-Treasurer, Dr Harold A Sofield, Chicago, Illinois

The other members of the Board are

Dr J Spencer Speed, representing the American Medical Association,
Dr Joseph A Freiberg, Dr Guy A Caldwell, Dr Francis M McKeever — representing The American Academy of Orthopaedic Surgeons
Dr J Warren White, Dr H Earle Conwell — representing The American Orthopaedic Association

Some changes in regulations have also been announced Full information may be obtained by wr to the Secretary, Dr Harold A Sofield, 6 North Michigan Avenue, Chicago, Illinois

The Seventh International Congress on Rheumatic Diseases was held at the Waldorf-Astoria Hotel in New York City, May 30 to June 3. Dr. Philip S. Hench of the Mayo Clinic was Chairman of the General Committee on Arrangements. Dr. Loring T. Swaim served for Dr. Ralph Pemberton, who was unable to be present because of illness. Dr. Pemberton was President of the *Ligue Internationale contre le Rhumatisme* as well as of the Pan American League for the Study and Control of Rheumatic Disease. These two organizations cooperated with the American Rheumatism Association, of which Dr. Richard H. Freyberg was President, in plans for the Congress.

The Plenary Sessions were held at the Waldorf-Astoria Hotel, the Clinical Sessions were held at Bellevue Hospital, Mt. Sinai Hospital, New York Hospital, Polyclinic Hospital, Goldwater Memorial Hospital, Presbyterian Hospital, Hospital for Special Surgery, Hospital for Joint Diseases, St. Luke's Hospital, Institute of Rehabilitation and Physical Medicine, and University Hospital, New York University. A program of unusual interest was presented.

About one hundred foreign guests were present. A two-week itinerary of various arthritis clinics of the country, following the Congress, was planned for these guests.

The Executive Board of the **American Public Health Association** announces that the Seventy-seventh Annual Meeting of the Association, and meetings of related organizations, will take place in New York, N. Y., October 21–28. The Hotel Statler and Hotel New Yorker will be joint headquarters.

According to an announcement recently made by Dr. E. R. Weidlein, Director of the Mellon Institute, that organization will again join with the University of Pittsburgh's School of Medicine in holding a symposium on orthopaedic appliances at the Institute during the week of September 19, 1949. The First Symposium, which was successful in every respect, has been cited as "a dynamic example of cooperation among scientists, physicians, engineers, and technicians".

The Second Symposium, also sponsored by the Sarah Mellon Scaife Foundation through its multiple Fellowship on Orthopaedic Appliances in the Institute, will be open to invited orthopaedic physicians and surgeons, as well as to selected orthopaedic technologists, skilled in brace design, fitting, and construction. The lecturers will include a number of nationally recognized authorities in orthopaedics, as well as scientists of Mellon Institute. They will give detailed attention to the problems of braces in cerebral palsy, paraplegia, and hemiplegia, resulting from poliomyelitis and other disabling diseases, to scoliosis and related spinal conditions, and to other specialized orthopaedic problems.

Inquiries concerning attendance and program details should be addressed to the **Orthopaedic Appliance Fellowship,** Mellon Institute, 4400 Fifth Avenue, Pittsburgh 13, Pennsylvania.

The National Foundation for Infantile Paralysis, Inc., announces short courses, for physicians, in the diagnosis and treatment of poliomyelitic patients. These short courses are:

Training Center	*Scheduled Courses*	*For Detailed Information and Enrollment, write to*
Children's Hospital, Boston, Massachusetts	August 15–19	William T. Green, M.D.
City Hospital, Cleveland, Ohio	July 18–23, August 8–13, August 29–September 3	John A. Toomey, M.D., Dept. of Contagious Diseases
D. T. Watson School of Physical Therapy, Leetsdale, Pennsylvania	1–3 weeks, depending on need of each individual. Dates to be specially arranged. Emphasis on when to prescribe the respirator and when the rocking bed, with variations to meet the needs of each patient.	Jessie Wright, M.D., Medical Director
Georgia Warm Springs Foundation, Warm Springs, Georgia	3–6 months, starting October 3	Robert L. Bennett, M.D., Director of Physical Medicine
University of Colorado Medical Center, Denver, Colorado	November 14–19	Winona C. Campbell, M.D., Director of Poliomyelitis Teaching Program

THE AMERICAN ORTHOPAEDIC ASSOCIATION

The Sixty-second Annual Meeting of The American Orthopaedic Association, under the presidency of Dr Ralph K Ghormley, was held at the Broadmoor, Colorado Springs, Colorado, May 18 through 21, 19[illegible]

Through the courtesy of the Rocky Mountain Orthopaedic Club, with Dr Robert G Packard and D[illegible] Atha Thomas as chairmen, the members of the Association attended a Clinical Day in Denver on May [illegible]

The scientific program as presented by the Program Committee follows

WEDNESDAY, MAY 18

Morning Session

Osteochondromata Arising from Articular Cartilage
James Vernon Luck, M D, Los Angeles, California (by invitation)
Discussion Allan F Voshell, M D, Baltimore, Maryland,
Hugh T Jones, M D, Los Angeles, California,
J Albert Key, M D, St Louis, Missouri

Correction of Deformity and Prevention of Aseptic Necrosis in Late Cases of Slipped Femoral Epiphy[illegible]
Edward L Compere, M D, Chicago, Illinois,
Clinton L Compere, M D (by invitation)
Discussion C Leslie Mitchell, M D, Detroit, Michigan,
Beckett Howorth, M D, New York, N Y,
Paul B Magnuson, M D, Chicago, Illinois,
Harold B Boyd, M D, Memphis, Tennessee,
Edward L Compere, M D, Chicago, Illinois

Congenital Dislocation of the Hip with Particular Reference to Its Pathogenesis—Treatment by Op[illegible] Reduction and Results
Beckett Howorth, M D, New York, N. Y
Discussion Vernon L Hart, M D, Minneapolis, Minnesota (by invitation)

The Trumble Operation for Fusion of the Hip Joint
George W Van Gorder, M D, Boston, Massachusetts

A New Technique for Arthrodesis of the Hip
Alan DeForest Smith, M D, New York, N Y,
Orien D Baab, M D, New York, N Y (by invitation)
Discussion Carl E Badgley, M D, Ann Arbor, Michigan,
Alberto Inclan, M D, Havana, Cuba

The Effects of Radio-Activity on Bone
John Z Bowers, M D, Washington, D C (by invitation)
Discussion John R Moore, M D, Philadelphia, Pennsylvania,
Joseph S Barr, M D, Boston, Massachusetts

Noon First Executive Session

Afternoon Session

A Conference, sponsored and arranged by the Joint Committee on Postgraduate Education of Th[illegible] American Orthopaedic Association and The American Academy of Orthopaedic Surgeons

1 Introductory remarks by the Chairman
A R Shands, Jr, M D, Alfred I duPont Institute, Wilmington, Delaware

2 The Ideal Curriculum
A For Adult and Fracture Training
Alan DeForest Smith, M D, New York Orthopaedic Hospital, New York, N Y
B For Children's Training
William T Green, M D, Children's Hospital, Boston, Massachusetts
C For Basic-Science Instruction
Guy A Caldwell, M D, Tulane University, New Orleans, Louisiana

3 The Ideal Curriculum of Resident Training in
A A University Clinic
Carl E Badgley, M D, University of Michigan, Ann Arbor, Michigan
B A Private Clinic
James S Speed, M D, Campbell Clinic, Memphis, Tennessee

4 Resident Training in a Government Hospital
A Veterans Administration
Dana M Street, M D, Kennedy Veterans Hospital, Memphis, Tennessee (by invitation)
B United States Army
Lieutenant Colonel Milton S Thompson, M C, Brooke General Hospital, Fort [illegible] Houston, Texas (by invitation)

5 Special Training the Resident Should Have in
  A Cerebral Palsy
      Robert A Knight, M D , Campbell Clinic, Memphis, Tennessee (by invitation)
  B Infantile Paralysis
      R L Lenhard, M D , Johns Hopkins Hospital, Baltimore, Maryland
  C The Fitting and Making of Braces and Prostheses
      Atha Thomas, M D , Denver, Colorado
6 Special Training the Resident Should Have in
  A Related Subjects Physical Medicine, Roentgenology, Neurology, and Rheumatology
  B Research and Publications
      Fremont A Chandler, M D , University of Illinois, Chicago, Illinois
7 The Graduate School of Medicine Course in Orthopaedic Surgery and Its Curriculum
      I T Nicholson, M D , University of Pennsylvania Graduate School, Philadelphia, Pennsylvania
8 What Constitutes a Satisfactory Preceptorship Training
      J Albert Key, M D , Washington University, St Louis, Missouri
9 Comments from The American Board of Orthopaedic Surgery on Board Certification and Resident Training
      Francis M McKeever, M D , Los Angeles, California
10 The American College of Surgeons and Specialty Training
      Philip D Wilson, M D , The Hospital for Special Surgery, New York, N Y
11 The American Medical Association and Specialty Training
      F H Arestad, M D , Associate Secretary of the Council on Medical Education and Hospitals (by invitation)
12 Discussion and Summary

THURSDAY, MAY 19

Morning Session

The Orthopaedic Treatment of Tuberculosis of the Spine in a Military Tuberculosis Center
  Lieutenant Colonel Harold S McBurney, Denver, Colorado (by invitation)
    Discussion David M Bosworth, M D , New York, N Y
Fusion of the Shoulder Joint in Children, Utilizing Autogenous Bone Graft
  Charles R Rountree, M D , Oklahoma City, Oklahoma
    Discussion James Vernon Luck, M D , Los Angeles, California (by invitation)
Conclusions Concerning the Use of Refrigerated Bone in Orthopaedic Surgery
  Philip D Wilson, M D , New York, N Y
    Discussion James S Speed, M D , Memphis, Tennessee
Trials and Tribulations in Attempted Femoral Lengthening
  H Relton McCarroll, M D , St Louis, Missouri
    Discussion LeRoy C Abbott, M D , San Francisco, California
The Congenital Kyphotic Tibia
  Carl E Badgley, M D , Ann Arbor, Michigan
    Discussion Clarence H Heyman, M D , Cleveland, Ohio,
      Wallace H Cole, M D , St Paul, Minnesota
Correlation of Myelographic and Operative Findings in Intervertebral-Disc Lesions
  J Albert Key, M D , St Louis, Missouri
Cauda Equina Tumors as a Cause of the Low-Back Sciatic Syndrome
  James W Toumey, M D , Boston, Massachusetts
    Discussion Joseph S Barr, M D , Boston, Massachusetts,
      Lenox D Baker, M D , Durham, North Carolina
A Report on the Trip to England of the American and Canadian Orthopaedic Groups
  Donald W Blanche, M D , Los Angeles, California (by invitation)

FRIDAY, MAY 20

Morning Session

The Patella Its Importance in the Derangement of the Knee
  Edwin F Cave, M D , Boston, Massachusetts,
  Carter R Rowe, M D , Boston, Massachusetts (by invitation)
    Discussion Harry C Blair, M D , Portland, Oregon
Acute Non-Tuberculous Psoas Abscesses
  Isadore Zadek, M D , New York, N Y
    Discussion I William Nachlas, M D , Baltimore, Maryland
Giant-Cell Tumors in Children
  Harold D Palmer, M D , Denver, Colorado (by invitation)

Factors which Influence Survival in Bone Sarcoma
C Howard Hatcher, M D , Chicago, Illinois
Discussion Robert W Johnson, Jr , M D , Baltimore, Maryland,
Robert I Harris, M B , Toronto, Ontario, Canada
Circulatory Changes in the Extremities, Associated with Infantile Paralysis and the Relation to Occurrence of Shortening
William T Green, M D , Boston, Massachusetts,
Thomas Gucker, M D , Boston, Massachusetts (by invitation),
Margaret Anderson, M S , Boston, Massachusetts (by invitation)
Discussion John L McDonald, M D , Toronto, Ontario, Canada
Presidential Address
Ralph K Ghormley, M D , Rochester, Minnesota

SATURDAY, MAY 21

Morning Session
Restriction of Growth of Bone by Pins through the Epiphyseal Cartilage Plate
Sylvan L Haas, M D , San Francisco, California
Discussion Walter P Blount, M D , Milwaukee, Wisconsin,
William T Green, M D , Boston, Massachusetts,
Gerald G Gill, M D , San Francisco, California
Congenital Metatarsus Varus
J Hiram Kite, M D , Atlanta, Georgia
Discussion Harold A Sofield, M D , Chicago, Illinois,
Walter P Blount, M D , Milwaukee, Wisconsin,
Philip D Wilson, M D , New York, N Y ,
Joseph A Freiberg, M D , Cincinnati, Ohio
An End-Result Study of the Keller Procedure
Mather Cleveland, M D , New York, N Y ,
Edward M Winant, M D , New York, N Y (by invitation)
Discussion Samuel Kleinberg, M D , New York, N Y
Ski Injuries—Trauma of Lower Extremities Resulting from Torsion Strain
John R Moritz, M D , Sun Valley, Idaho (by invitation)
Discussion Atha Thomas, M D , Denver, Colorado
Noon Final Executive Session

Robert W Johnson, Jr , M D , Baltimore, Maryland, is President of The American Orthopaedic Association for the year 1949 to 1950

At the final Executive Session of this Association, the following officers, members of committee, and delegates were elected

Officers
President-Elect James S Speed, M D , Memphis, Tennessee
Vice-President John L McDonald, M D , Toronto, Ontario, Canada
Secretary C Leslie Mitchell, M D , Detroit, Michigan
Treasurer Frank D Dickson, M D , Kansas City, Missouri
Committee Members
Membership Committee David M Bosworth, M D , New York, N Y
Program Committee Walter P Blount M D , Milwaukee, Wisconsin
Research Committee James W Toumey, M D , Boston, Massachusetts
Delegate to the American College of Surgeons
Henry W Meyerding, M D , Rochester, Minnesota
Representatives on the American Board of Orthopaedic Surgery
Herman C Schumm, M D , Milwaukee, Wisconsin,
Harold A Sofield, M D , Chicago, Illinois
The following were elected to active membership in The American Orthopaedic Association
Edgar M Bick, M D , New York, N Y ,
Garry deN Hough, Jr , M D , Springfield, Massachusetts,
John C McCauley, Jr , M D , New York, N Y ,
Hugh Smith, M D , Memphis, Tennessee,
Frank Stinchfield, M D , New York, N Y ,
Hugh A Thompson, M D , Raleigh, North Carolina

The Journal of Bone and Joint Surgery*

American Volume

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July 1949

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Suggestions for Contributors

While *The Journal of Bone and Joint Surgery* is published by The American Orthopaedic Association and The British Orthopaedic Association, contributions of interest to orthopaedic surgeons are welcome from all countries of the world

Manuscripts offered for publication in the American Volume should be sent to the Editor, *The Journal of Bone and Joint Surgery*, 8 The Fenway, Boston 15, Massachusetts

Manuscripts submitted for publication in the British Volume should be sent to the Editor, *The Journal of Bone and Joint Surgery*, 45 Lincoln's Inn Fields, London, W C 2, England

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Instructions to Contributors to American Volume

All articles are acknowledged as soon as received, and a reply is sent as to their disposition as soon as possible after that date Since the manuscripts are read by members of the Board of Associate Editors and often are discussed at the meetings of the Board, there may be unavoidable delay

Articles are accepted only with the understanding that they are contributions exclusively to this *Journal*

Manuscripts

All manuscripts should be typewritten, with double spacing and good margins The original should be submitted, the author keeping a copy, as the original of an accepted article will not be returned

Figures under 100 should be written out, except when used for percentage or degrees, or where decimals are involved

When direct quotations are used, they should include the exact page numbers on which they appeared in the book or article from which they were taken

A list of legends for the illustrations should be included

The bibliography should include only references mentioned in the text It should be double spaced and arranged alphabetically, and the following forms used

Reference to an article author's name and initials, title of the article, name of periodical, volume number, inclusive pages, and year of publication

Reference to a book name of author and initials, title of book, edition number, city of publication, publisher, and year of publication

Accuracy in the preparation of bibliographies will save much time and correspondence

Illustrations

Careful consideration must be given to the number of illustrations accepted with each article It is seldom necessary to republish illustrations

Good illustrations in *The Journal* are only possible from good copy Black and white glossy prints of photographs should be furnished Direct-contact glossy prints from the original roentgenograms should be submitted These usually reproduce more satisfactorily than do prints from secondary negatives

The magnification of all photomicrographs should be given

Original drawings should be furnished, photographs of drawings do not reproduce well If there is printing on the drawings, it should be large enough to be readable after the necessary reduction

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VOL. 31-A, NO. OCTOBER 1949

The Journal of Bone and Joint Surgery

American Volume

THE INFLUENCE OF THE CONTACT-COMPRESSION FACTOR ON OSTEOGENESIS IN SURGICAL FRACTURES*

BY G. W. N. EGGERS, M.D., THOMAS O. SHINDLER, M.D., AND CHARLES M. POMERAT, PH.D., GALVESTON, TEXAS

From the Department of Orthopaedic Surgery and the Department of Anatomy, University of Texas School of Medicine, Galveston

The results of physical forces on osseous structures have been recorded for a long time by observers of morphological characteristics. That bone conforms architecturally to new stress and strain created by deformity and trauma was expressed in 1892 by Julius Wolff, who advanced the theory that every change in the form and function of a bone or in its function alone is followed by certain definite changes in its internal architecture and equally definite secondary alterations in its mathematical laws. The principle expressed has since been known as Wolff's law, but, because of the physiological variables, Wolff could never reduce the observation to mathematical accuracy[1].

Hugh Owen Thomas expressed his observations in 1883: "The presence of vitality in the body is a factor in aiding us to mechanically correct even mechanical defects, as eccentric forms, that cannot be altered in the dead body, without rupture or fracture, can, during life, be altered by mechanical influence, as time and physiological action will commode the part to the direction of the employed force."

In 1929, Fell and Robison showed, by explanting a segment of embryonic femoral cartilage, that the femur would develop on the same general lines as in the normal limb. Thus, the structures possess an inherent factor of configuration.

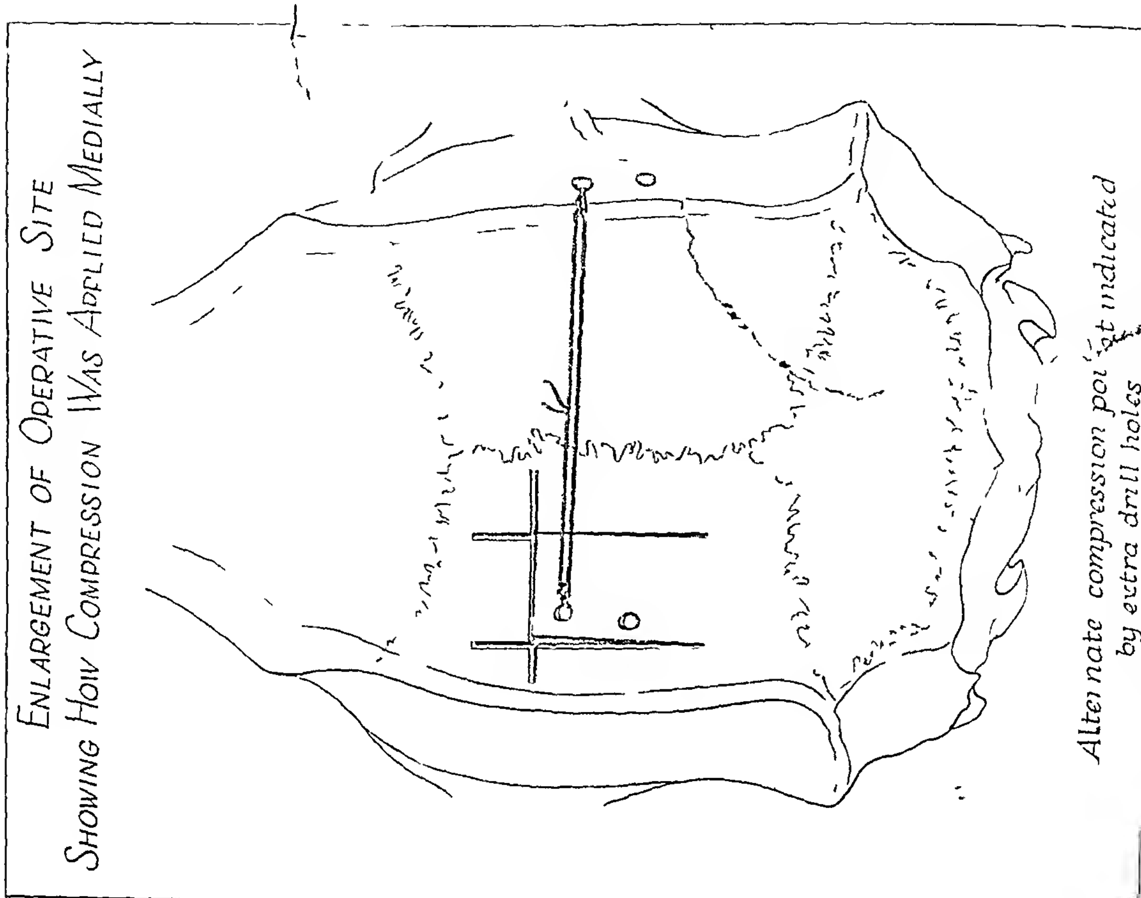
These clinical observations and experimental findings are not in conflict and suggest that a bone, although inherently designed, may respond later with architectural changes.

Glucksmann, in 1938, showed an effect of compression *in vitro*; he subjected endosteal cultures to pressure by placing them in intercostal muscle between two growing ribs. Oriented structures were produced in unoriented bone tissue.

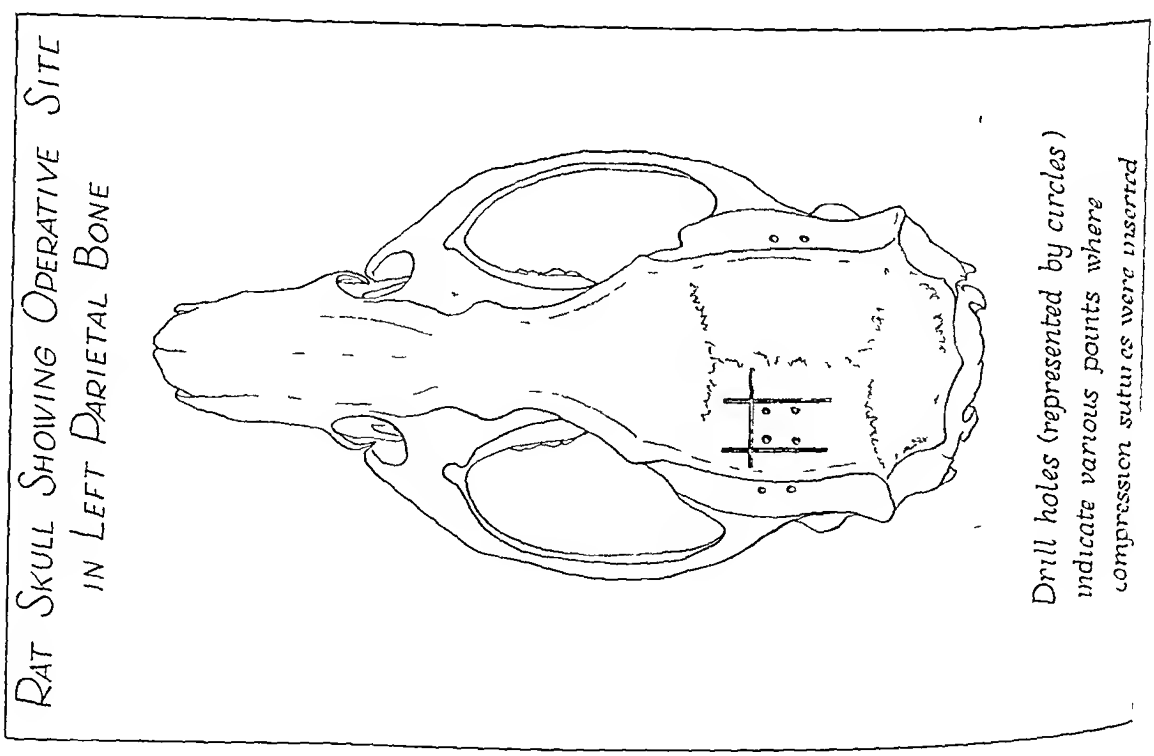
To determine the influence of a compression force in osseous repair and to test its consistency were the purposes of the experimental work to be presented. To create a controlled investigative condition which involves so many physiological variables presented almost insurmountable difficulties. Study was made of the femora and tibiae in dogs and in rats, but the data were discarded since accurate controls could not be instituted.

The problem of securing living bone free from compression, tension, or muscular influences, yet adequate for the application of experimental devices to produce a controllable artificial force, was resolved by the selection of the parietal bone of adult rats. It was considered that this selection would provide a highly critical test of the hypothesis suggested, since membrane bone is notably poor in its osteogenetic response[9].

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 25, 1949.



Showing Manner of Serial Sectioning
From Behind Forward (in direction of arrow)



Application of Lateral Compression

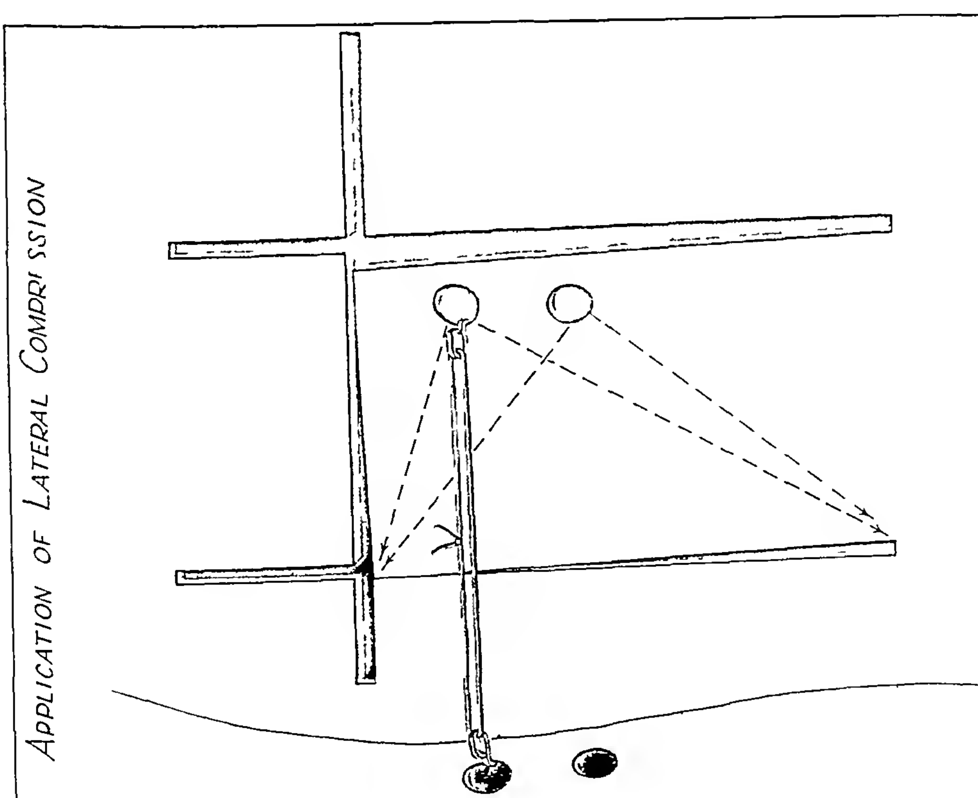


Fig 3

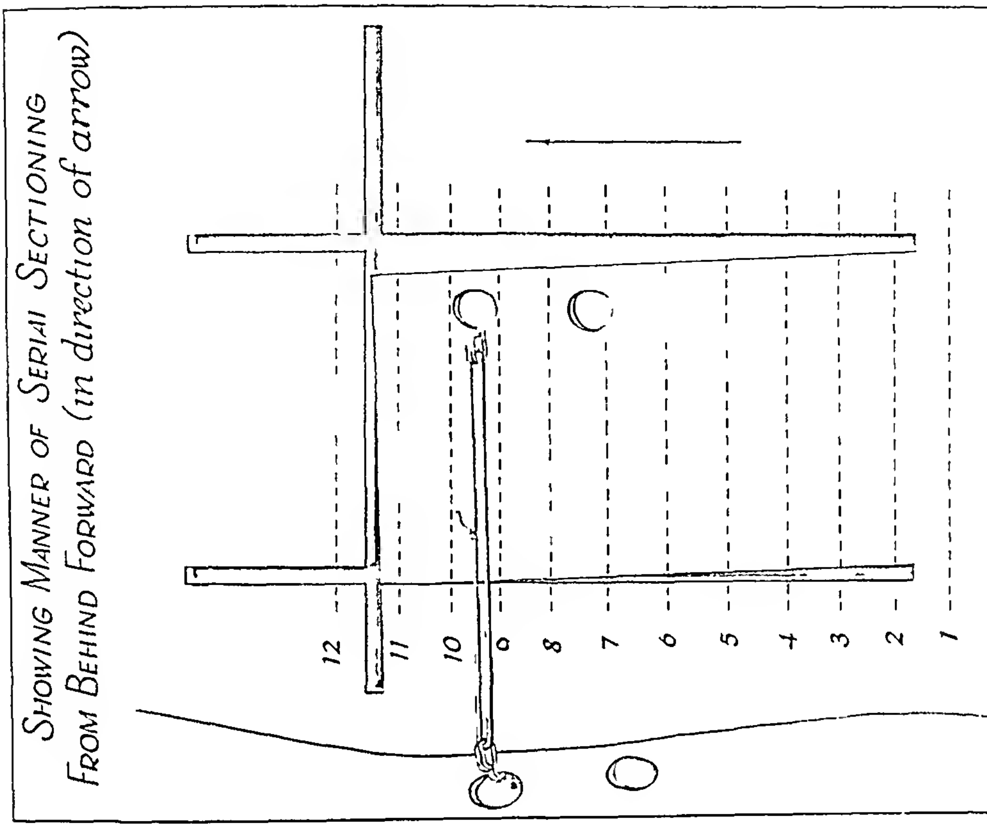


Fig 4

Fig 3 Application of lateral compression Representative vector forces are indicated by arrows
Fig 4 Manner of serial sectioning

TECHNIQUE

The experimental operative procedures were performed under inhalation ether anaesthesia with three instrument-sterilization techniques,—that is, without antisepsis, with alcohol antisepsis, and with heat antisepsis. After longitudinal incision of the skin and superficial fascia over the middle of the skull of mature white rats, the procedure consisted in making a three-sided flap in the left parietal bone (Fig. 1) with a rotary saw, 150 micra thick and 1.38 centimeters in diameter. One cut was made parallel to the sagittal suture, another 2 to 3 millimeters lateral to this, and a third connecting the two anteriorly. The flap with its periosteum and blood supply remained attached behind, providing a point of fixed anchorage.

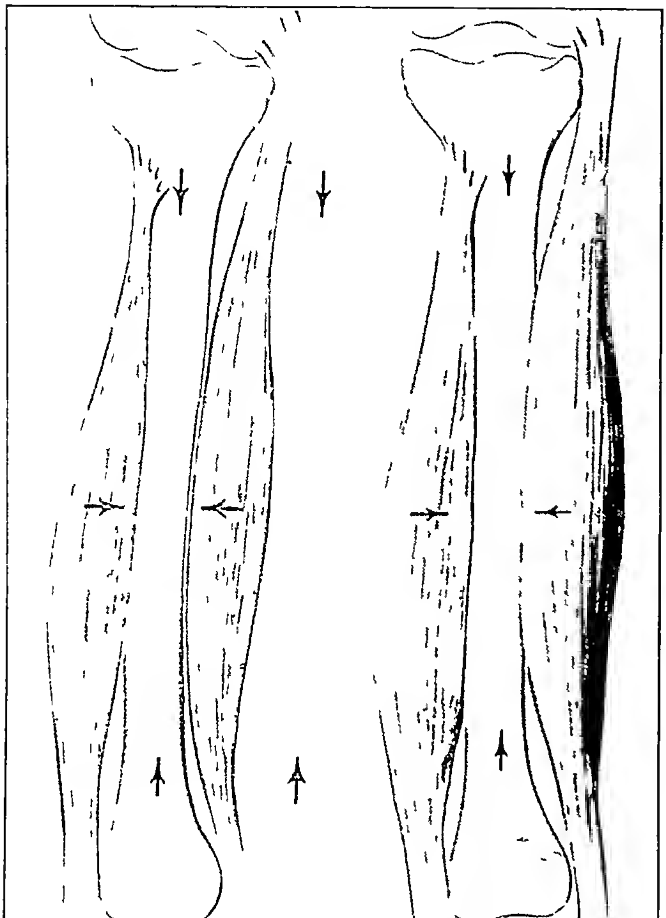


Fig. 5-A   Fig. 5-B

Diagrammatic representation of longitudinal and transverse muscular compression forces on a long bone.

Fig. 5-A. Muscle tone exerts a more or less constant factor.

Fig. 5-B. Voluntary contraction increases the transverse and longitudinal compression factor.

In the application of lateral compression, a small hole was drilled in the flap anteromedially and another laterally at the same level through the left temporal bone, after the temporal muscle had been reflected. Cotton thread (No. 8), put through these holes extradurally and extracranially, was tied tightly so that the bone flap turned slightly laterally, approximating with some compression the bony margins of the lateral cut and leaving the margins of the medial cut separated by not more than 300 micra at the anterior pole. The skin and superficial fascia were closed with interrupted cotton sutures.

In the application of medial compression, the three-sided flap was made in a similar manner, but a hole was drilled in the anterolateral aspect of the flap and the corresponding drill hole was made in the right temporal bone. A small stainless steel wire hook was placed into each of these two holes, and the two hooks were connected with a rubber band under tension (Fig. 2). The skin and superficial fascia were closed over the appliance. By varying the point of the drill holes in the bone flap and the corresponding ones in the temporal bones, the distribution of the total force applied could be varied (Fig. 3).

At intervals following the operation, the animals were sacrificed, the appliances were removed, and the entire flat surface of the calvarium of each rat was excised circularly and placed in 10 per cent. Zenker-formalin solution, followed by decalcification in 2 per cent. hydrochloric acid and embedding in paraffin. The skull of each animal was serially cross-sectioned from behind forward (Fig. 4), making a combined total of more than 1200 sections which were observed after staining with hematoxylin and eosin.

Eighteen animals were successfully operated upon in this experiment. This includes

FIG 6

Osteogenesis of endochondral bone in femur of an adult rat (× 150)

thirteen in which the contact-compression factor was applied and five in which it was omitted Sections from ten animals are included in the illustrations Of the eleven animals in which the contact-compression factor was applied and which were sacrificed after the fifteenth postoperative day, ten showed a favorable response to the force applied None of the animals not subjected to the contact-compression factor showed any significant osteogenetic activity

Discussion of Technique

Each specimen of animal skull presented a field of study in which there was an area of static flap control (Fig 4,*12*), a movable flap, to the margin of which the contact-compression factor could be applied (Fig 4,*1* to *11*), the opposite, non-compressed control flap margin, and an undisturbed skull margin (Fig 4, arrow)

The experimental technique described furnished material which was placed under mechanical stress, applied on a margin of choice One free margin of the bone flap was compressed anteriorly, but, proceeding posteriorly, the degree of compression decreased, and finally there was no contact at all Thus, material with contact and compression, with contact and excessive pressure, and with compression and no contact could be observed

Since it was not possible experimentally to ensure contact without some compression, and since it was shown in these experiments that compression could be produced without contact, the authors selected the term "contact-compression factor" This factor is, therefore, the combination of contact and the force to promote contact, exerted on bone structures for which osseous union or osteogenesis is desired

The contact-compression factor is constantly considered in the work on osseous structures with which surgeons and orthopaedic workers are associated In dealing with these problems, the factor is unwittingly utilized, purposely violated, or surgically created It is reasonable to assume that contact demands compression to some degree It is also possible

that a compression force may be exerted throughout a bony structure without contact on the affected margin

The contact-compression factor consists of two parts (1) contact of surfaces under compression, and (2) the compression force, endeavoring to bring into actual contact fracture surfaces which are only opposed In a fracture the compression may consist of either of two forces,—internal or external, each is exerted on the fracture surfaces

The internal force is physiological and is created by the muscles The force is composed of two parts,—the muscle tone and voluntary muscle contraction The muscular forces are effective in many planes, as in the vertebrae or pelvis, but two directions, the longitudinal and transverse, are more dominant as applied to long bones The transverse pressure is exerted by the mass of the muscle structure, especially in the voluntary contraction which increases the diameter of the muscle (Figs 5-A and 5-B) This is particularly effective, because of the fact that the musculature is practically always contained within a fascial sheath of some type or degree The longitudinal force is due to muscle tone and is greatly influenced by muscle contractions The certain fact of all muscular forces is that they are variable in proportion to the muscular activity

The external contact-compression force is due to non-physiological forces, such as gravity, weight-bearing, and surgical methods, which may follow an anatomical pattern

Fracture reduction of opposing surfaces results in partial contact and much approximation Surgical procedures, such as arthrodesis and grafting of bone, cannot be expected to furnish perfect contact, but present a relatively large surface approximation Thus, the securing of bony union or osteogenesis is dependent on the osteogenetic effort of the involved bone surfaces As indicated in these experiments, the influence of the contact compression factor is clinically important[2 3 5 8]

RESULTS

In the interpretation of the experimental findings, the authors were aware of many

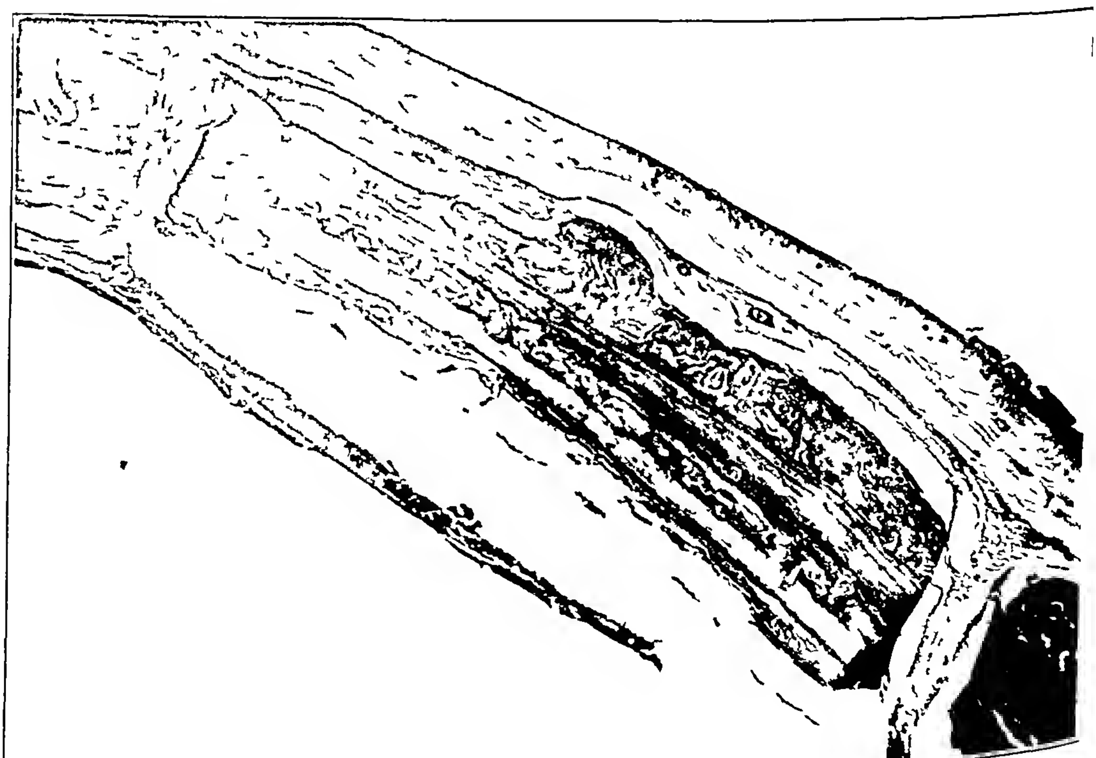


Fig 7-A

Area 12, sixteen days (× 40) No contact-compression factor was applied to this area of flap No effort at union of fracture margins is evident (This is the control area of Figs 8-A, 8-B, and 8-C)

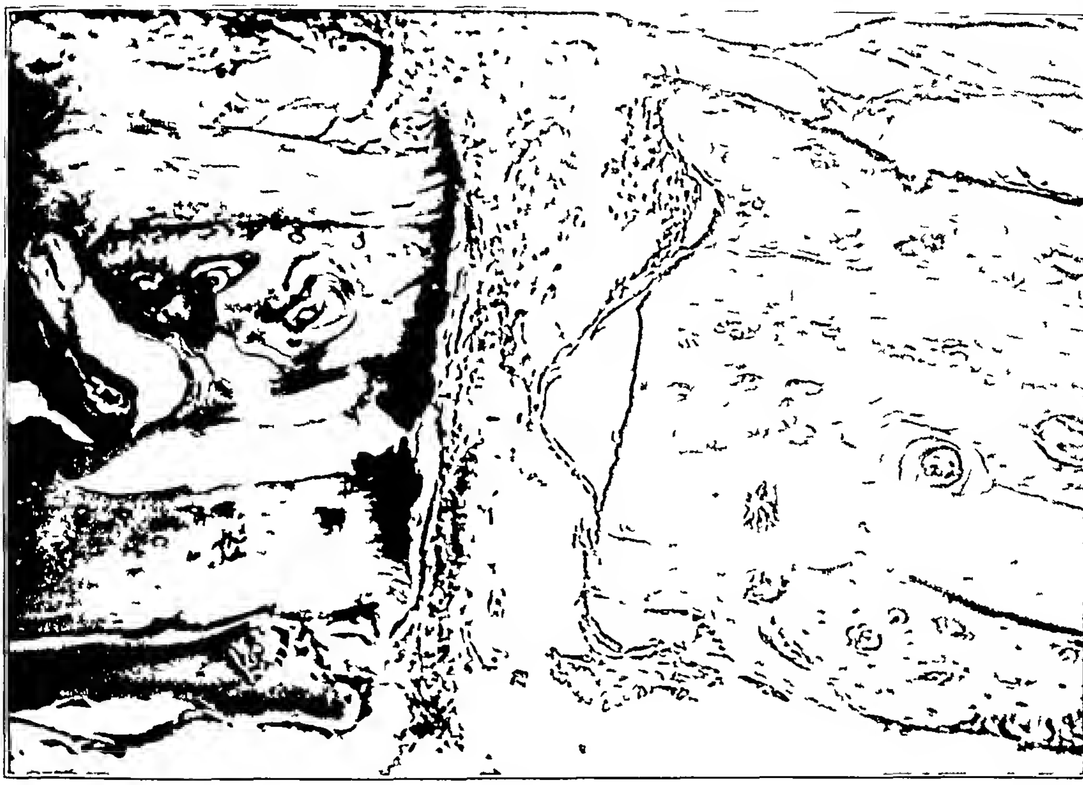


Fig. 7-B

Lateral cut (× 150). There is no purposeful osteogenesis for union.

Fig. 7-C

Medial cut (× 150). There is no purposeful osteogenesis for union.

conditions affecting osteogenesis and, without altering or analyzing them, have attempted to keep the physiology of experimental fields of the control and of the affected part un-

tually identical by conducting both in the same animal within a limited transverse physical space of about 2,500 micra Thus, in the experiments, the control margin can be seen simultaneously in the low-power microscopic field with the experimental margin of the bone studied It is reasonable to assume that no great physiological variation would be present in such close proximity

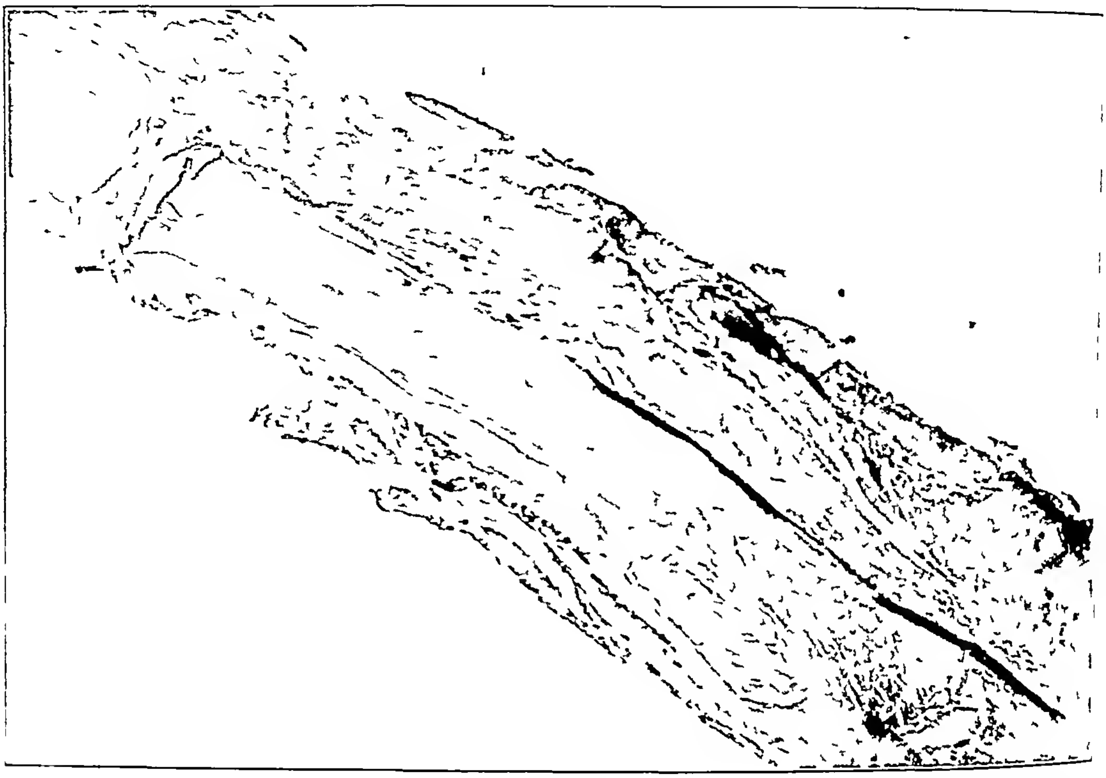


FIG 8-A

Area 11 sixteen days Medial contact-compression factor was applied There is osteogenetic activity of medial margin (× 40)

FIG 8-B

Lateral cut (× 150) Fibrous tissue is present in fracture interval

FIG 8-C

Showing osteogenesis of membranous bone in adult rat Medial cut (× 150) Osteogenetic activity, fragmentation, and osteoblastic invasion of reticular network may be noted The osteogenetic activity is identical with that in Fig 6

The basic osteogenesis of bone is the same in membranous and endochondral bone (Figs 6 and 8-C) Each presents primarily a reticulo-collagenous network, followed by

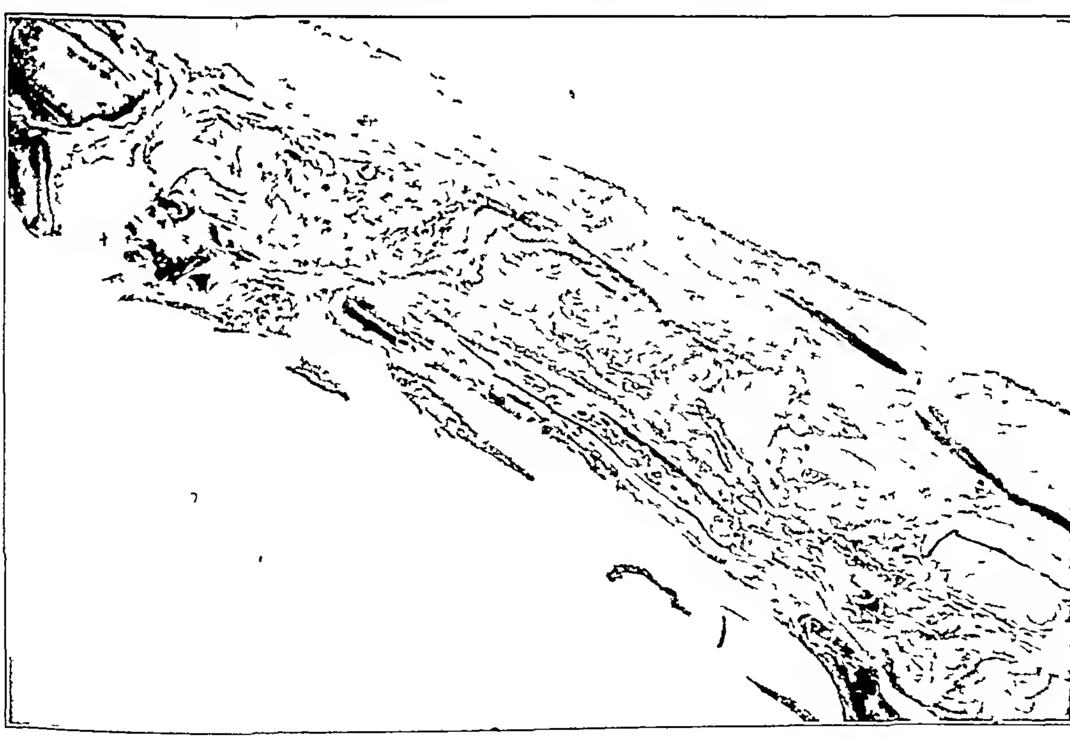


FIG 9-A

Area 7, sixteen days Medial contact-compression factor was applied Section made through edge of compression hole (× 40) Note pressure necrosis due to excess pressure on lateral margin Osseous activity occurs on medial side

osteoblastic invasion and deposition of calcium salts Cartilage may be seen in membranous as well as endochondral bone, as observed by Pritchard

The figures of the microscopic studies are oriented so that uniformly the lateral border

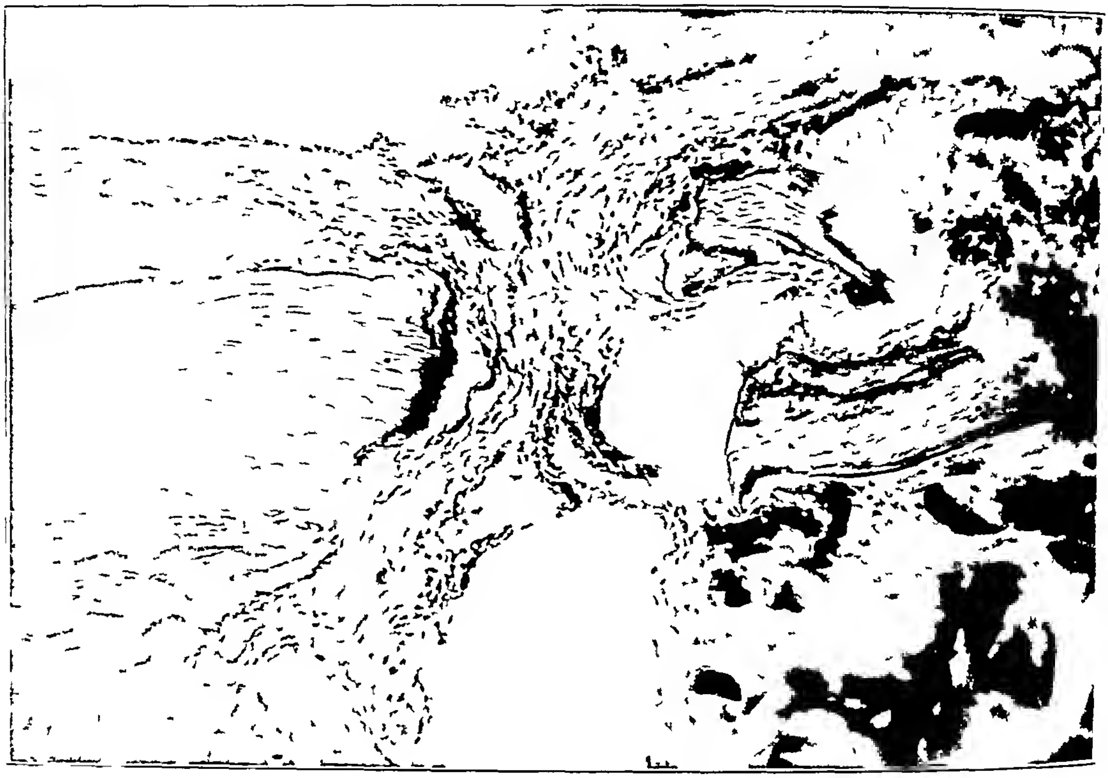


FIG 9-B

Lateral cut (× 150) Lateral flap margin shows necrosis and fragmentation

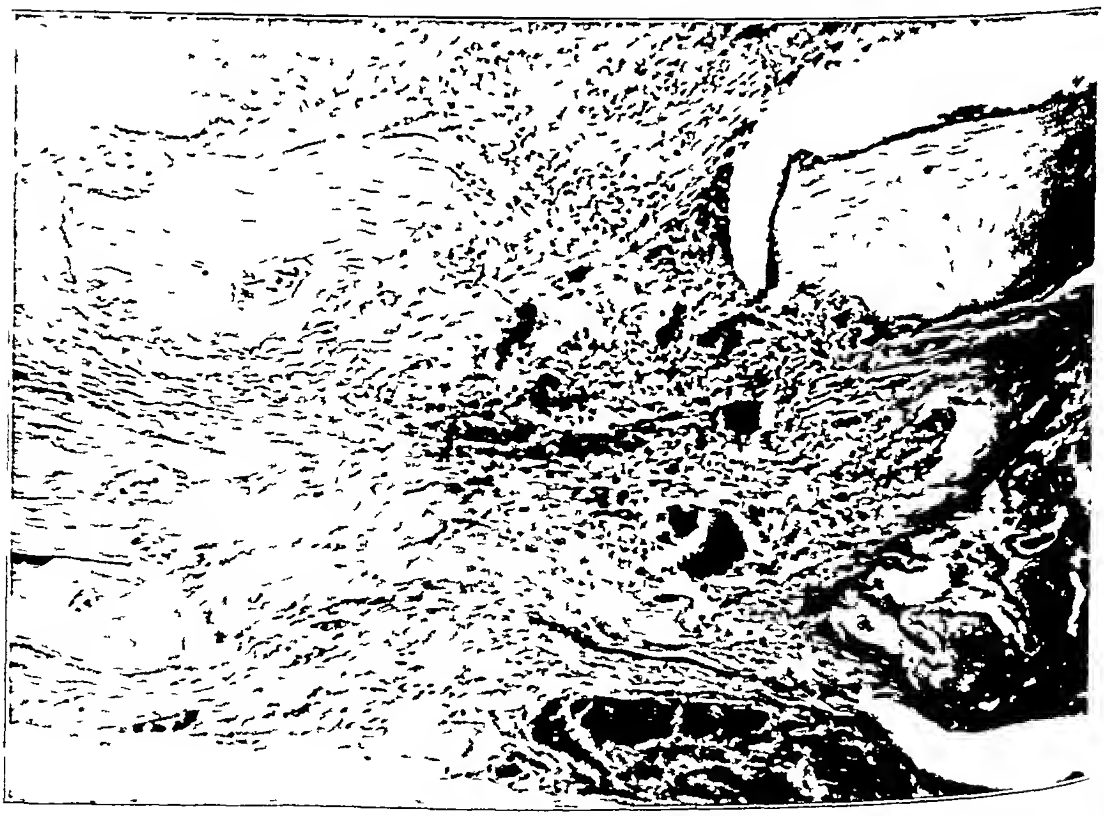


FIG 9-C

Medial cut (× 150) There is active osteogenesis in both margins of fracture interval

of the skull flap is on the reader's left, the medial side on the right, the cutaneous portion at the top, and the dural surface below. The gap due to the saw cut is usually obvious, and each section is shown in a low-power (× 40) and a higher-power magnification (× 150) of each surgical fracture. The age in days of each section indicates the number of days after operation at which the animal was sacrificed. The area number indicates the position on the bone flap from which that section was taken (Fig. 4).

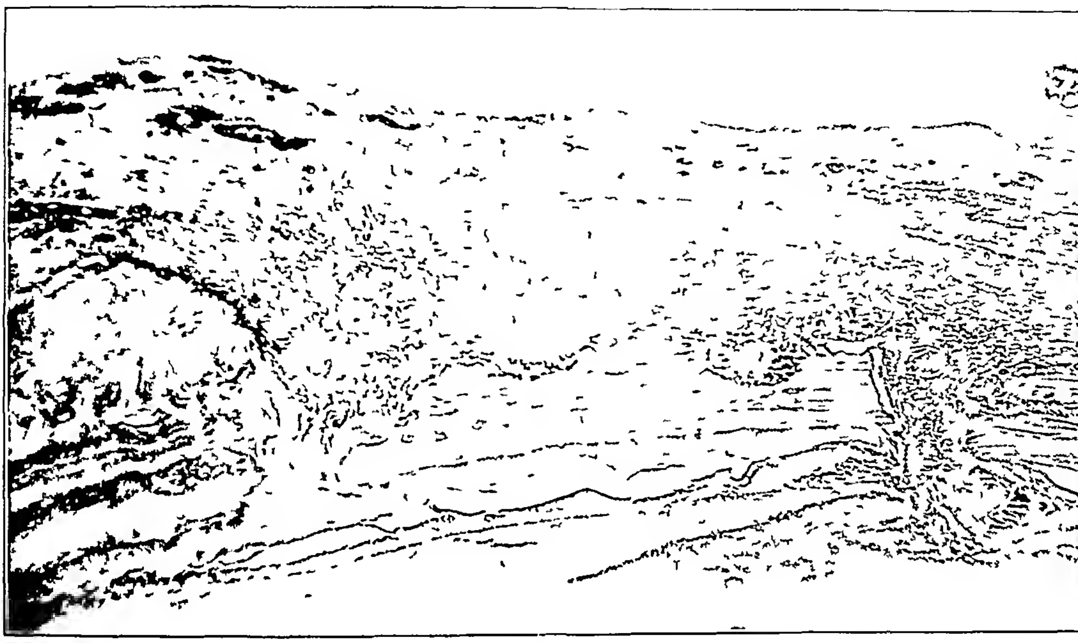


FIG. 10-A

Area 6, seventeen days (× 40). Lateral contact-compression factor was applied. Contrast the osseous union on lateral aspect with fibrous tissue in fracture gap on medial side.

FIG. 10-B

Lateral cut (× 150). Showing union of lateral margin.

FIG. 10-C

Medial cut (× 150). There is fibrosis and no union of medial fracture margin.

Of eighteen animals employed in this experiment, the results in all those sacrificed on the sixteenth day or later are reported. Those sacrificed previous to the sixteenth postoperative day showed little or no osteogenetic activity.

Area 12. Sixteen Days. There was medial compression of the flap, but no contact-compression factor was applied to this portion. A bone flap was prepared according to the

FIG. 11-A

Area 8, seventeen days (× 40). Lateral contact-compression factor was applied. Infection occurred; note necrosis and inflammatory cells. New-bone formation has occurred on lateral margin.

FIG 11-B

Lateral cut (× 150) There is osseous activity on side of contact-compression factor in infected area Saw-cut margin is seen on left

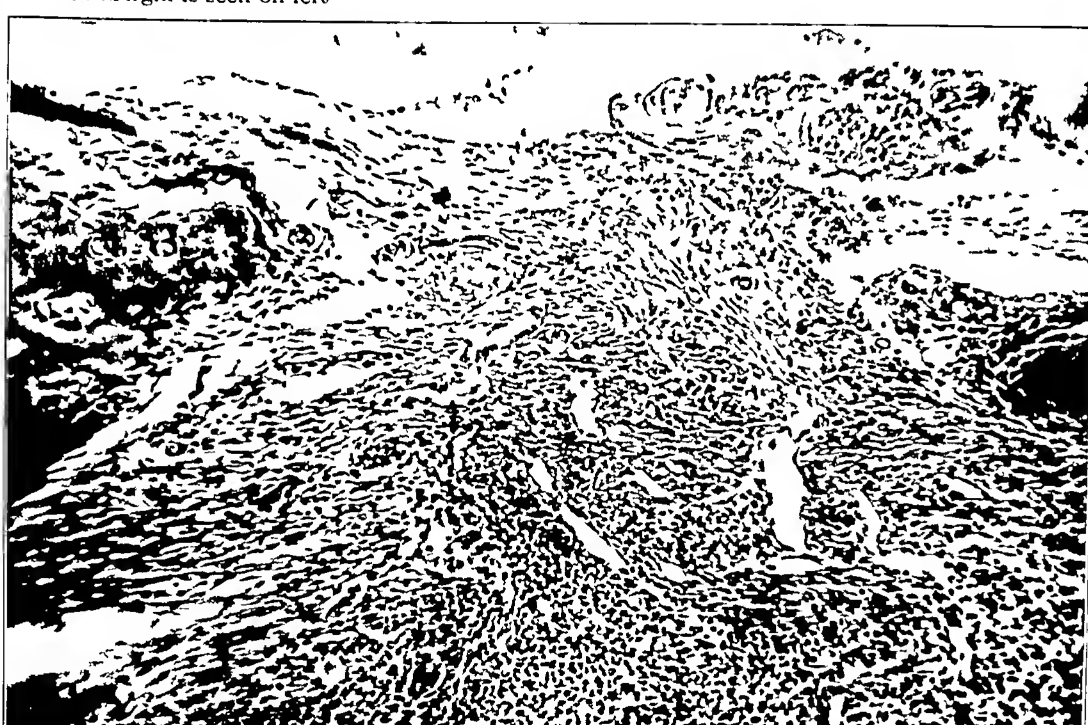


FIG 11-C

Medial cut (× 150) Showing necrosis of bone and inflammatory cells on medial side There is no attempt at union

routine technique, but no pressure was applied to the control flap margins (Area 12) These remain relatively passive with no invasion of the fracture interval, although there is some surface activity (Figs 7-A, 7-B, and 7-C) This is the control area of the experimental animal shown in Figures 8-A, 8-B, and 8-C

Area 11, Sixteen Days The contact-compression factor was applied to the medial side The lateral (control) margin presents no effort at union The medial side shows the formation of new bone, with simultaneous resorption of devitalized bone along the fracture margins and the typical reticulo-collagenous matrix (Figs 8-A, 8-B, and 8-C)

Area 7, Sixteen Days The medial contact-compression factor was applied This section was made through the edge of the drill hole in which the small metal hook was placed Under excessive pressure, this lateral area of the flap shows some necrosis and little osteogenesis The medial fracture margins show marked osseous activity, both sides having received the benefit of the contact-compression factor (Figs 9-A, 9-B, and 9-C)

Area 6, Seventeen Days The lateral contact-compression factor was applied The

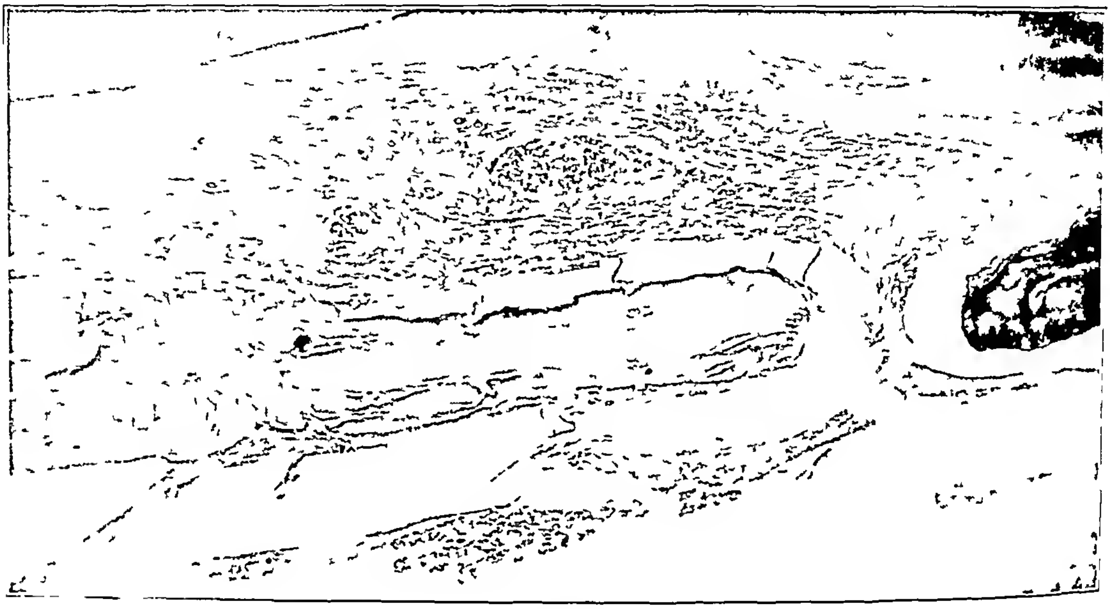


FIG 12-A

Area 8 twenty days (× 40) Lateral contact-compression factor was applied

FIG 12-B

Lateral cut (× 150) Showing osteogenesis and union

FIG 12-C
Medial cut (× 150) There is no effort at marginal union

fracture lines are well defined, and there is marked new-bone invasion with activity in the diploe and union on the lateral margin There is no effort at repair of the fracture gap on the medial side (Figs 10-A, 10-B, and 10-C)

Area 8, Seventeen Days Lateral application of the contact-compression factor has been made (Fig 11-A) This section was included because the animal was grossly infected The marked destruction of bone and the associated bone activity are clear Again, the important fact is that, in the presence of infection, osteogenetic activity is greater on the side (lateral) receiving the contact-compression factor The medial side shows only marked bone necrosis and resorption (Figs 11-B and 11-C)

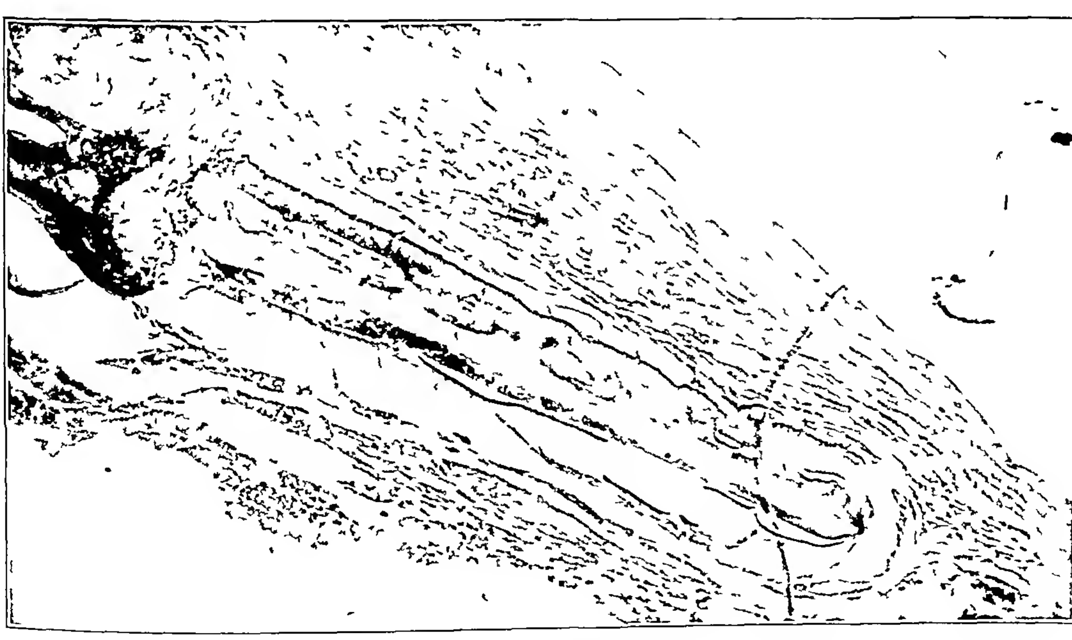


FIG 13-A
Area 9, twenty days (× 40) Lateral contact-compression factor was applied Union is active on lateral margin, fibrosis is present in medial gap

Area 11, Sixteen Days. The contact-compression factor was applied to the medial side. The lateral (control) margin presents no effort at union. The medial side shows the formation of new bone, with simultaneous resorption of devitalized bone along the fracture margins and the typical reticulo-collagenous matrix (Figs. 8-A, 8-B, and 8-C).

Area 7, Sixteen Days. The medial contact-compression factor was applied. This section was made through the edge of the drill hole in which the small metal hook was placed. Under excessive pressure, this lateral area of the flap shows some necrosis and little osteogenesis. The medial fracture margins show marked osseous activity, both sides having received the benefit of the contact-compression factor (Figs. 9-A, 9-B, and 9-C).

Area 6, Seventeen Days. The lateral contact-compression factor was applied. The

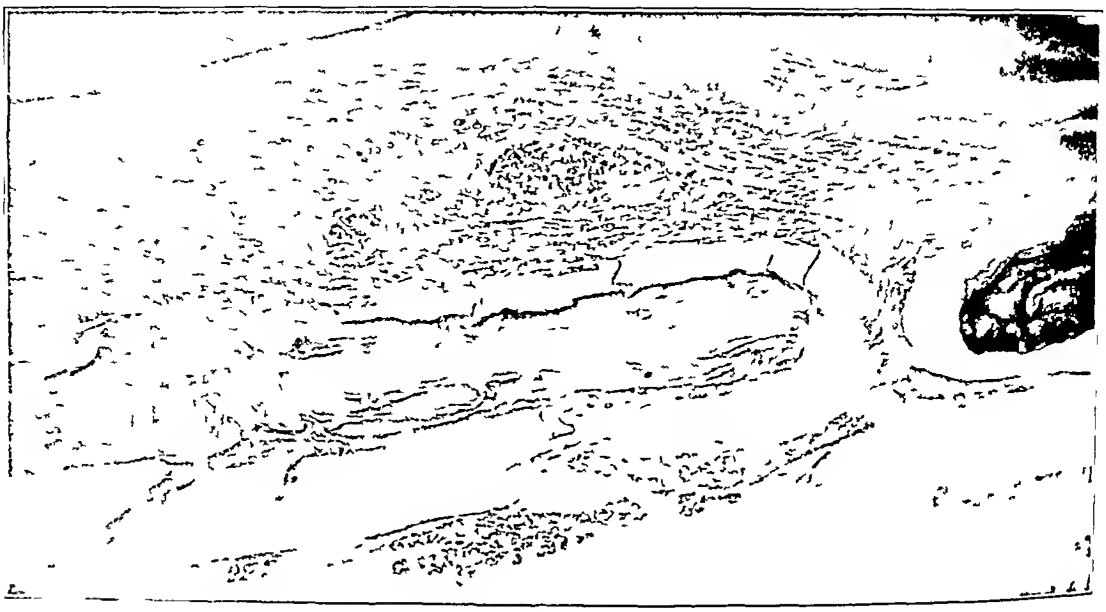


FIG. 12-A

Area 8, twenty days (× 40). Lateral contact-compression factor was applied.

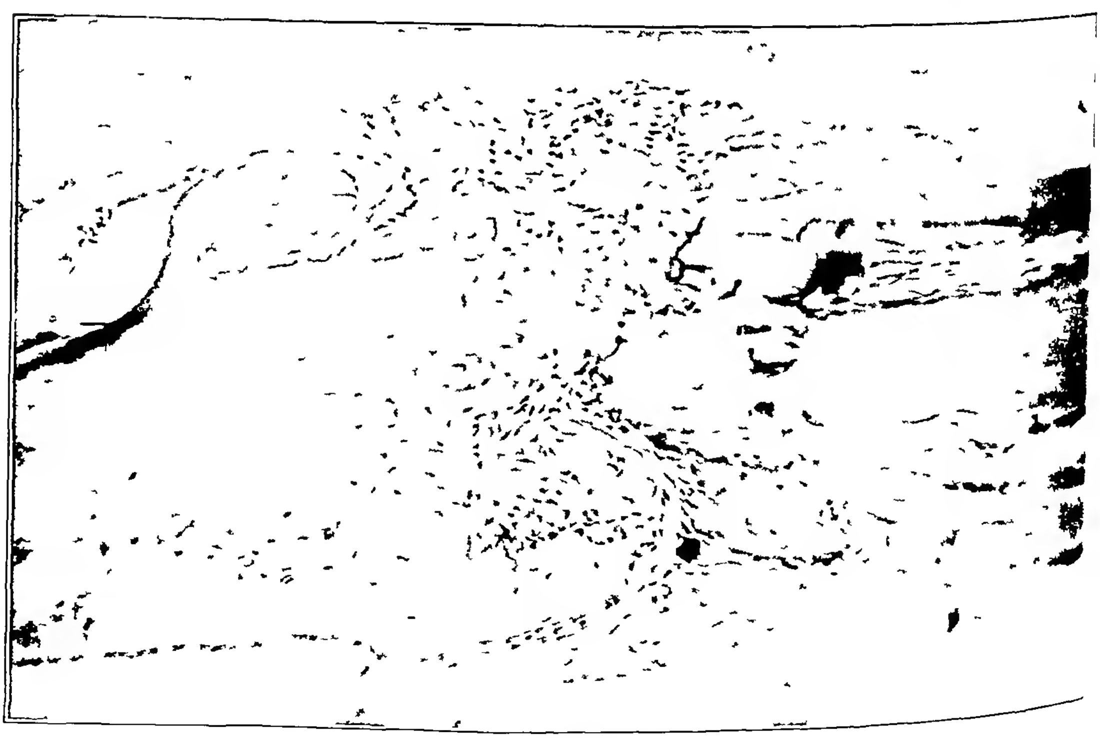


FIG. 12-B

Lateral cut (× 150). Showing osteogenesis and union.

Area 9, Twenty Days The lateral contact-compression factor was applied (Fig 13-A) The osseous activity is evident on the lateral aspect, but is lacking on the medial (control) side New bone is noted between the diploe, and early osteogenesis is seen between the fracture ends on the lateral border under the high-power magnification (Figs 13-B and 13-C)

Area 8, Twenty-eight Days The medial contact-compression factor was applied The basic findings are repeated Here the response is less complete, but the principle of reaction to pressure is constant (Fig 14-A) This section is interesting because of the osseous

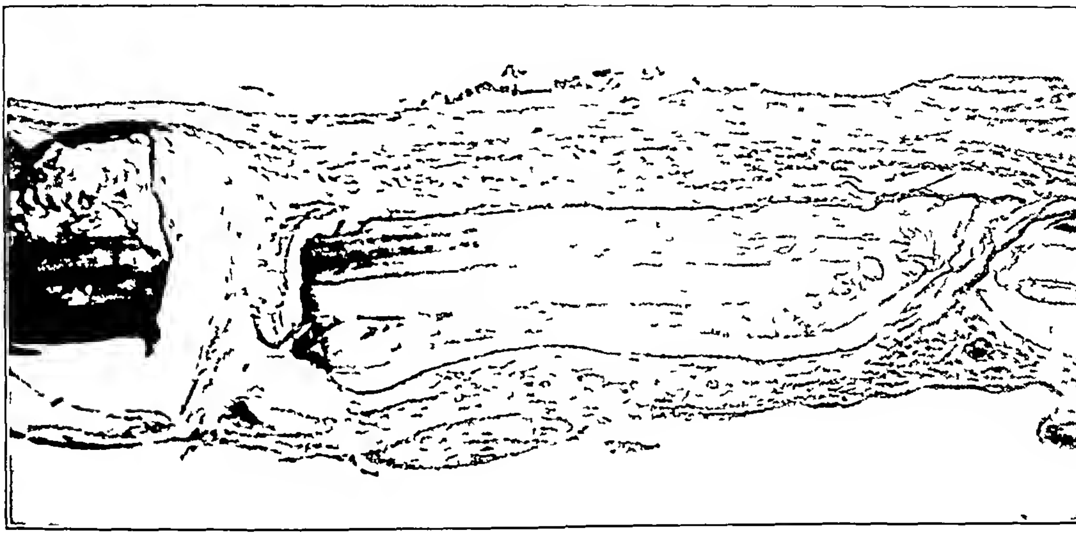


Fig 14-A

Area 8, twenty-eight days (× 40) There was medial compression, saw cut was oblique on medial side Some pressor effect was probably lost, which may explain why union is not complete on medial side

Fig 14-B

Lateral cut (× 150) There is no union of lateral fracture margins

FIG 14-C

Medial cut (× 150) Osteogenesis is active, especially on compressed margin There is an effort at gap closure by medial margin of flap

activity on the cutaneous side of the lateral skull margin, in contrast to the lateral aspect of the flap Even though there was osseous activity (positional osteogenesis), the contact compression factor was absent, and purposeful bony effort to bridge the lateral fracture gap is consequently lacking The lateral flap margin is under no mechanical pressure and is totally inactive (Figs 14-B and 14-C)

Area 9, Thirty-nine Days The medial contact-compression factor has been applied This section presents osseous activity on the medial side with union, the lateral border is ununited Actual contact of the fracture margins is not present, but the margins are

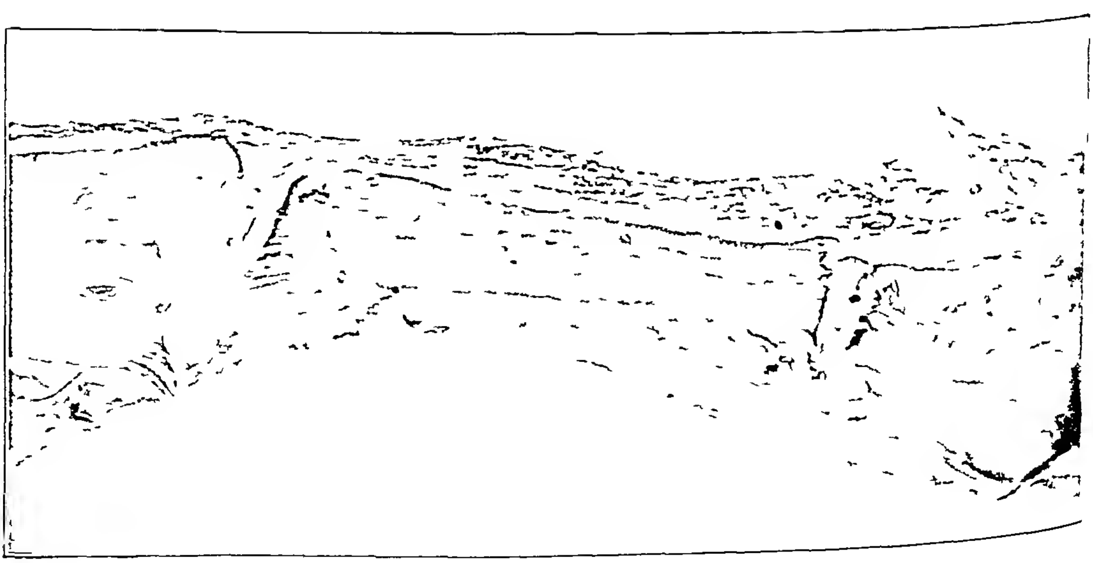


FIG 15-A

Area 9, thirty-nine days (× 40) Medial contact-compression factor was applied Osseous union has occurred on medial side, there is non-union of lateral margin

FIG. 15-B

Lateral cut (× 150). There is non-union. Osteogenesis is present, with no purposeful effort to fill the fracture interval from the lateral skull margin.

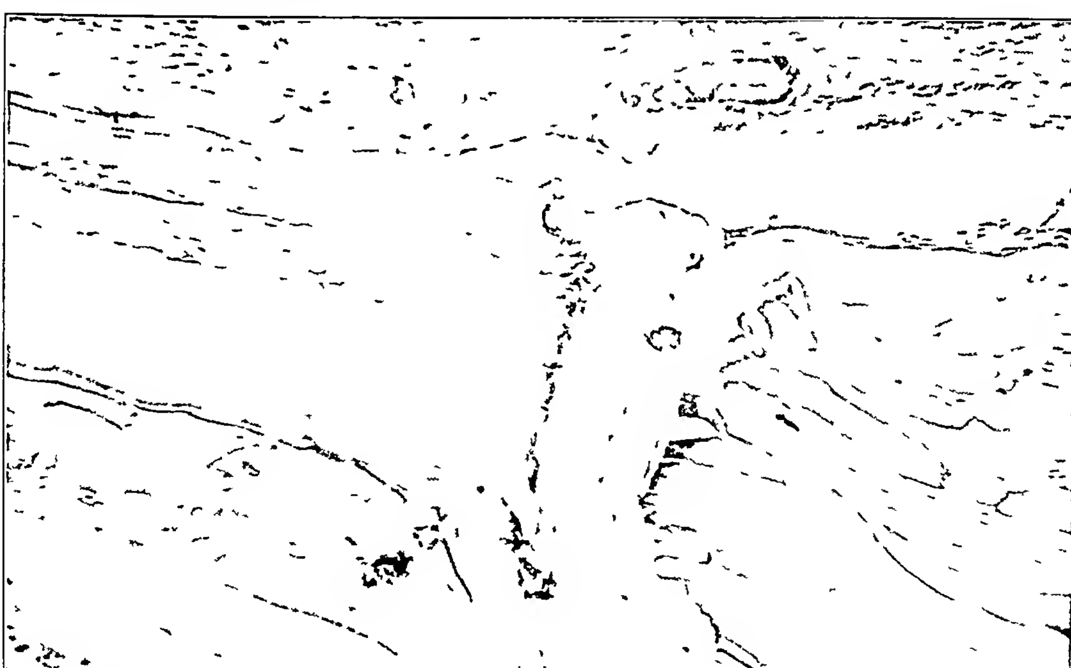


FIG. 15-C

Medial cut (× 150). Showing osseous union of approximated margins.

approximated. However, the osteogenesis proceeds across the fracture gap on the side of compression, but not on the non-compressed margin (Figs. 15-A, 15-B, and 15-C). This is significant.

Area 10, Forty-six Days. No contact-compression factor was applied. The contrast

with preceding illustrations is impressive The lateral fracture line presents an absence of osteoblastic activity, and the medial side shows only fibrotic organization (Figs 16-A, 16-B, and 16-C)

Area 9, Ninety-four Days No contact-compression factor was applied Both margins of the flap are ununited There is some osseous activity, but no union of either fracture

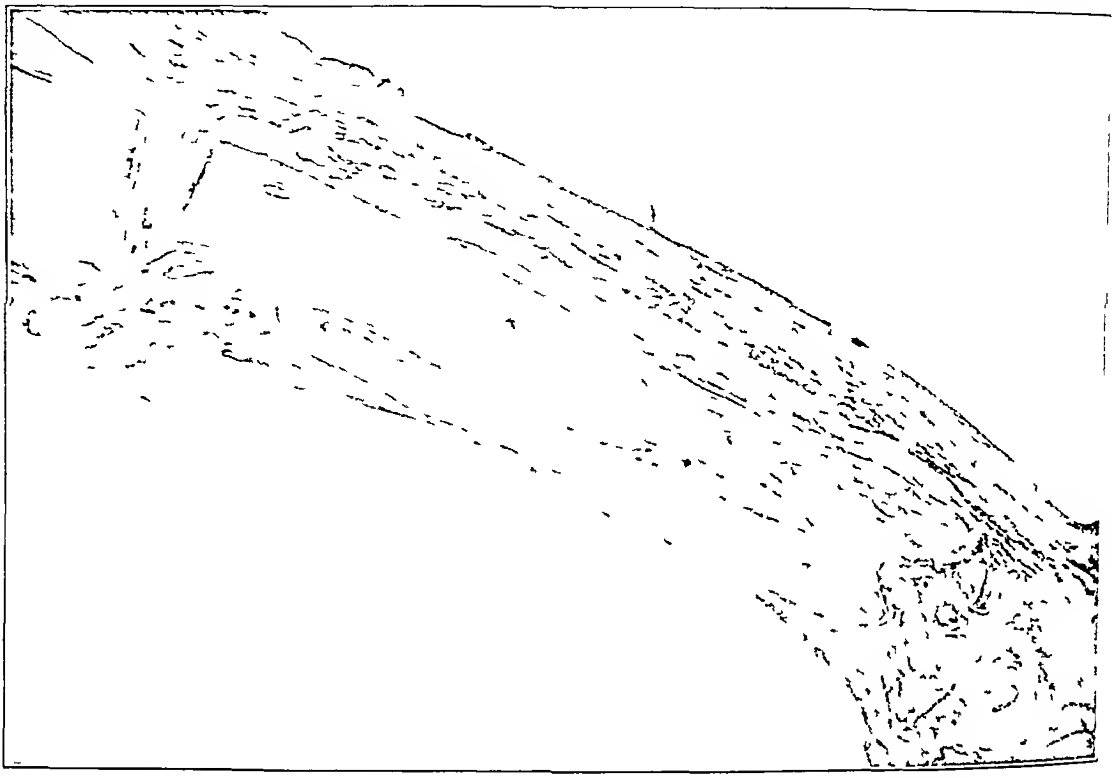


Fig 16-A

Area 10, forty-six days (× 40) No contact-compression factor was applied

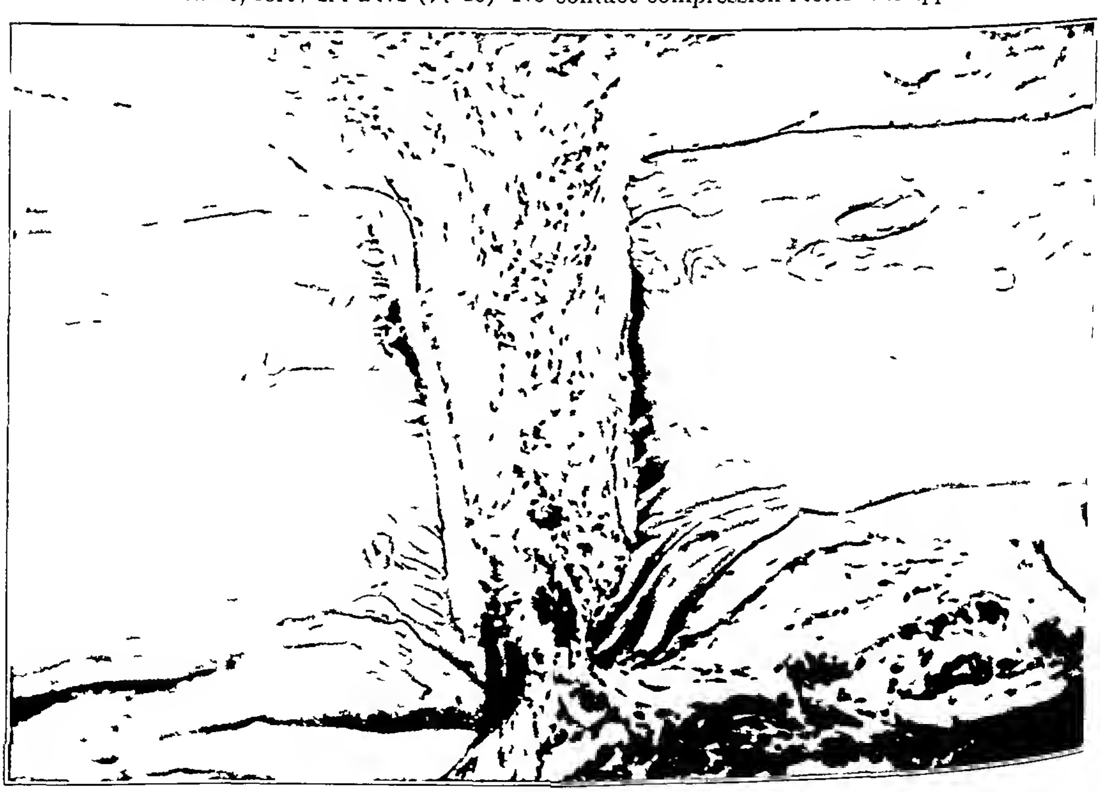


Fig 16-B

Lateral cut (× 150) There is absence of osteoblastic activity

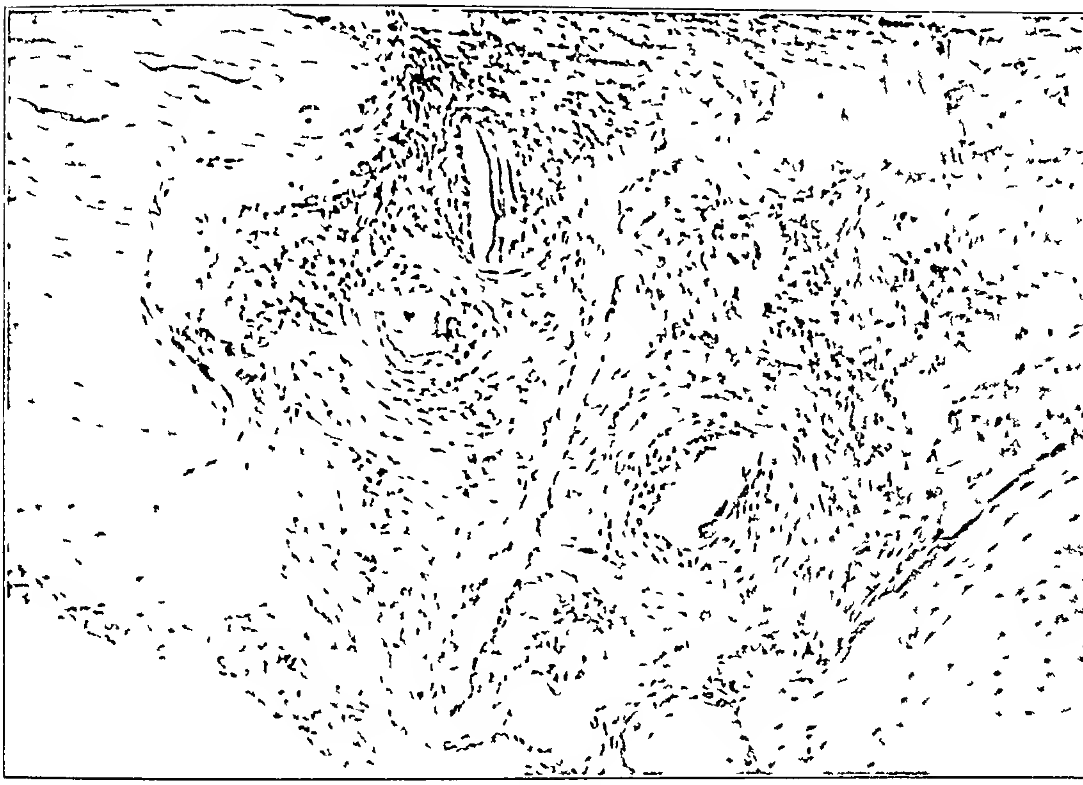


FIG. 16-C

Medial cut (× 150). Medial side shows only fibrotic organization.

margin (Figs. 17-A, 17-B, and 17-C). The significance of this ninety-four-day section with non-union is impressive, and becomes more so when contrasted with the seventeen-day sections on the side of the flap to which the contact-compression factor was applied and with the osteogenesis and union that followed.

COMMENT

The consistency of the findings throughout the experiments convinced the authors that the contact-compression factor was the only reasonable variable in the investigation. Union could be secured on either the medial or lateral aspect of the bone flap by choosing merely the side to unite and then applying the contact-compression factor to that side. If no union was desired, the flap was cut, and the contact-compression factor was not applied. Certainly, it seems reasonable to conclude that the contact-compression factor is important in stimulating osteogenesis and securing osseous union of fracture surfaces. The consistency and persistence of the same findings become impressive as one examines section after section, hundreds or more, and the findings are found to have been repeated in the same orderly fashion. This response of bone to the contact-compression factor can be utilized to clinical advantage.

The margins which received excessive pressure and contact became necrosed with a delay in osteogenesis; the margins under a more ideal pressure and contact had excellent osteogenetic activity, and the approximated margins with pressure applied made a determined osseous effort to bridge the intervening fracture gap. The serial sections clearly show the reaction to the varying pressure. Thus, the contact-compression factor with too much force caused necrosis; when absent, there was no osteogenetic response. These findings have convinced the authors that the optimal pressure is somewhere within the physiological limits of the force exerted by the musculature of the individual concerned.

SUMMARY

Experimentally, the authors produced union and purposeful osteogenesis in surgical

fractures in the area selected by applying the contact-compression factor alone The microscopic sections are the factual evidence of this accomplishment

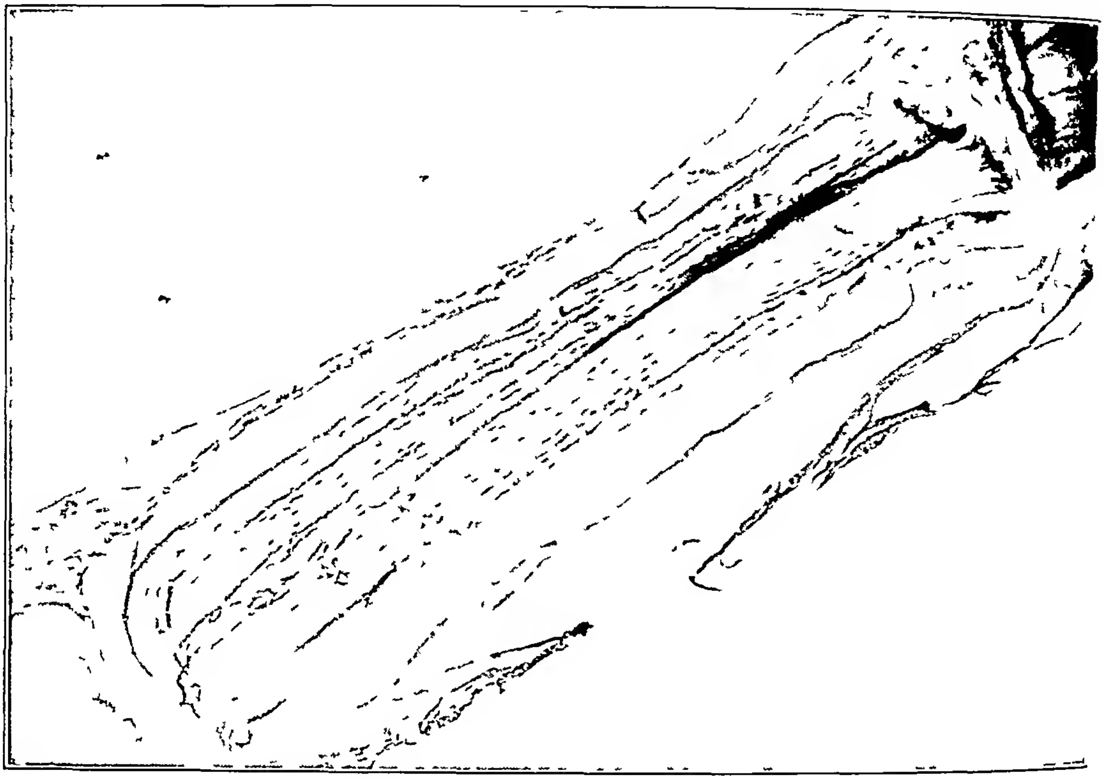


FIG 17-A

Area 9, ninety-four days (× 40) No contact-compression factor was applied There is non union of medial and lateral margins

FIG 17-B

Lateral cut (× 150) Lateral fracture margins are not united

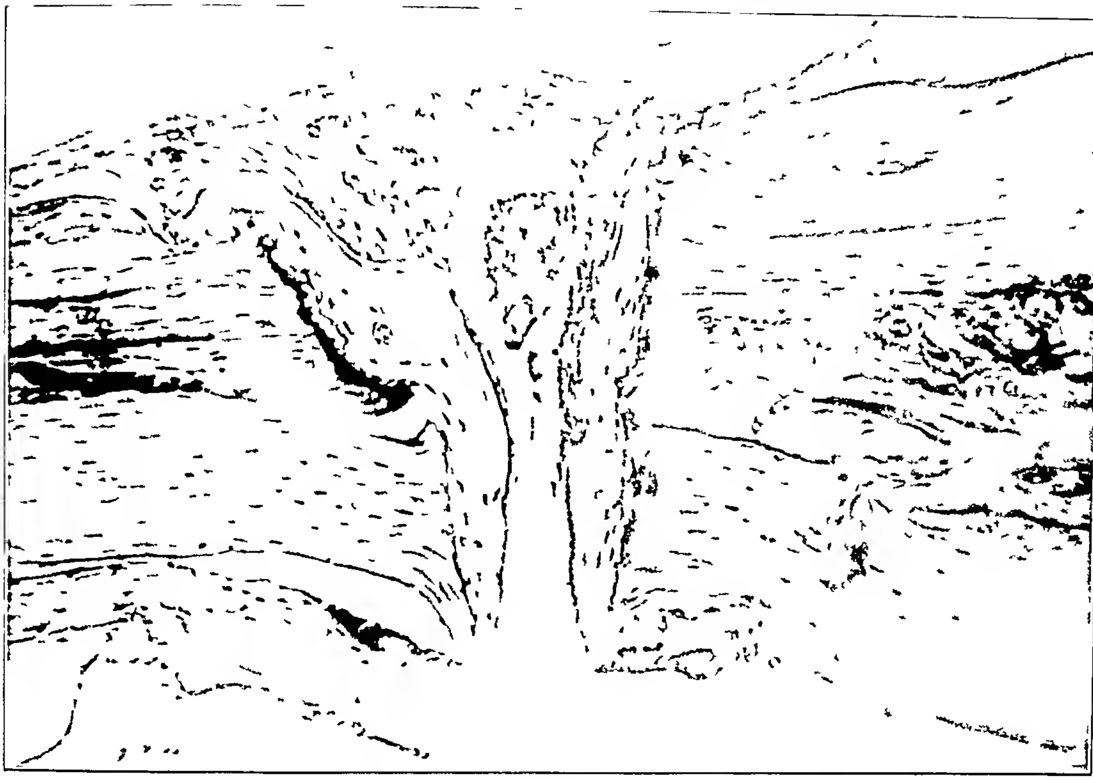


FIG 17-C
Medial cut (× 150) Medial fracture margins are not united

CONCLUSIONS

1 The contact-compression factor should incorporate compression forces in physiological muscle balance

2 The presence of the contact-compression factor favorably influences purposeful osteogenesis and fracture union Its absence fails to stimulate, but does not prevent, osteogenesis

3 The presence of infection in the fracture site does not alter the tendency for osteogenesis to be more active in the area upon which the contact-compression factor is exerted

4 Excessive pressure causes necrosis of the compressed bone, and lack of pressure fails to stimulate osteogenesis The most advantageous compression force on the fracture surfaces apparently is mid-way between the extremes, and probably is exerted by the physiological forces of the musculature of the parts involved, to which the osseous structures are adjusted

NOTE The authors wish to express their appreciation to the United States Army Medical Library, United States Naval Research Grant (N_6-onr-266), Medical Library, Department of Medical Illustration, and Miss Estelle Greenwalt, University of Texas School of Medicine

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DISCUSSION

DR HUGH SMITH, MEMPHIS, TENNESSEE Dr Eggers' thought-provoking paper is representative of the type of work in which orthopaedic surgeons must engage in the future,—namely, physiological and pathological investigation of the fundamental processes of orthopaedic phenomena The possibilities in clinical research, new surgical techniques, or mechanical appliances have not been exhausted, but the field is progressively narrowing Rather than embark upon clinical studies alone, we must now turn to more basic research for original ideas

From a purely clinical standpoint—and I have only clinical experience upon which to base my discussion—I believe that Dr Eggers' thesis is correct that contact-compression is one of the major mechanical factors in bone healing, and that clinical data substantiate his observations

To a person believing in the necessity for absolutely rigid fixation of fractures, the success of the hanging cast method of treating fractures of the humerus was somewhat disconcerting, and required a complete about-face in some of the fundamental beliefs in regard to bone healing It would seem that, provided shearing forces are eliminated, a slight amount of motion or laxity of healing bone surfaces is desirable However, both excessive motion and absolute rigidity should apparently be avoided

Dr Eggers' conclusions are most interesting and stimulating, and represent, I believe, a step in the right direction My ideas of bone healing must again be altered We have all been aware that diastasis adversely affects healing, and that apposition and contact are desirable Other than as a means of maintaining contact, the effects of compression on osteogenesis have not been fully appreciated or generally accepted As Dr Eggers so aptly puts it, "this factor has been unwittingly utilized, purposely violated, or surgically created" I think it is natural that we should not accept this, or perhaps have a little reticence in accepting this contact-compression factor, since we are well aware that excessive compression is responsible for necrosis or osteoclasis Dr Eggers' findings show that there is much to be learned in regard to optimal mechanical conditions for the healing of bones Certainly, there must be a common meeting ground for the various concepts of immobilization, positive pressure, or contact-compression

If the optimum amount of pressure can be determined and controlled, the more widespread adoption of intramedullary pins, particularly for the femur, slotted plates, or various other mechanical appliances which take advantage of this contact-compression factor would seem logical

DR EDWARD L COMPERE, CHICAGO, ILLINOIS This paper by Dr Eggers is both interesting and instructive The method of this controlled investigation is exceedingly ingenious and the results appear to be incontrovertibly accurate

Although this work has been done on bones which are preformed as membrane, while most fractures which the orthopaedic surgeon treats are in bones which are preformed in cartilage, Eggers states (and the experimental evidence seems to support his thesis) that the healing of fractures is identical in both membranous bone and in bone which has its origin in cartilage The experiments described here confirm the opinion expressed by Charnley in 1948 and by Eggers in the same year, in an article dealing with clinical cases,—namely, that moderate compression aids the healing of fractures and hastens the processes of bone repair and osseous union in arthrodesis operations

It is important that the clinician keep in mind the lessons which have been retaught by Dr Eggers,—that compression without bone contact, such as that created by metal against bone, causes absorption Marked compression-contact between two bones or between fragments of the same bone will produce necrosis The well-established principle is still ignored by men lacking adequate training or the understanding of orthopaedic principles,—that distraction, even though contact may be retained, will delay the healing of fractures, and that distraction with loss of contact may lead to non-union

In 1938, I carried out some experiments at the University of Chicago, in which I removed bone from the fibulae of dogs trephined the calvarium in the same area as did Dr Eggers, and switched the two bones, putting the fragment of fibula into the calvarium defect and bone of the calvarium into the defect created in the fibula The skull bone united to the fibula, while the bone from the fibula, which had no pressure factor holding it into position in the calvarium, was slow to form even fibrous union

The obvious conclusion from these experimental studies of Dr Eggers, supported as they are by clinical experience, would be that minimal compression-contact creates the ideal situation for the most rapid healing of fractures or the obtaining of fusion following arthrodesis operations The ideal compression forces are those created by the muscles themselves, as they envelop the bones of the extremities

THE TRUMBLE OPERATION FOR FUSION OF THE HIP *

BY GEORGE W. VAN GORDER, M.D., BOSTON, MASSACHUSETTS

From the Lakeville State Sanatorium, Middleboro, Massachusetts

Numerous methods of performing extra-articular fusion of the hip joint are recorded in the literature, and among these is one which the writer believes should be more widely recognized. It is an ischiofemoral type of arthrodesis, advocated in 1932 by Hugh C. Trumble of Melbourne, Australia. This operation is especially suitable in cases of tuberculosis of the hip, where the disease is located in the superior portion of the acetabulum and the ilium, as well as in the joint proper, and where an iliofemoral arthrodesis would not only have little chance of success, but might produce irreparable harm.

Historically, it is of interest that, in 1931, Galland quoted Calvé as predicting that the time would come when the tuberculous hip joint would be fused successfully by the construction of a buttress on the adductor side of the joint. Curiously enough, one year later, this is exactly what Trumble succeeded in accomplishing when he devised his ischiofemoral fusion operation. The principle of the operation is to establish a bridge of bone between the ischium and the femur, just below the hip joint, in an operative field which is supposedly free from tuberculous contamination (Fig. 1). With fusion of this bony bridge, which is promoted by the action of the adductor muscles of the thigh, strain is taken away from the diseased joint and healing of the tuberculous process is encouraged.

A description of the operation follows.

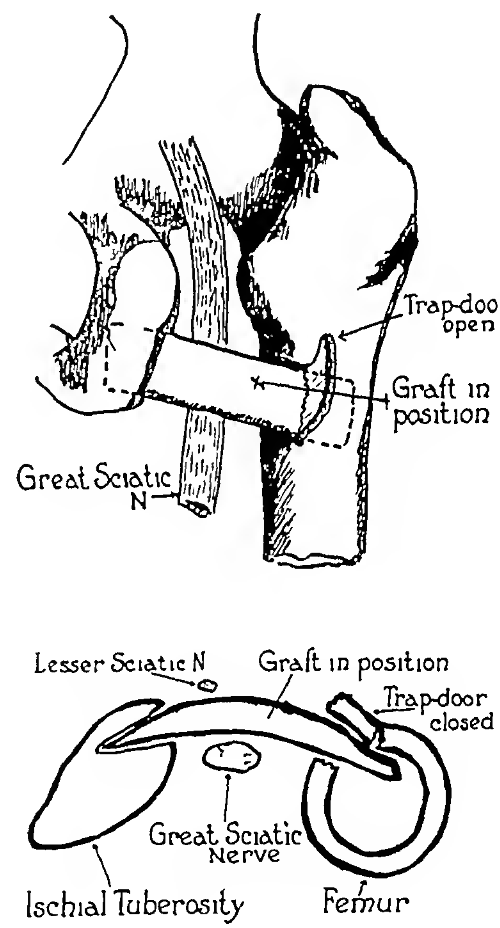


FIG. 1

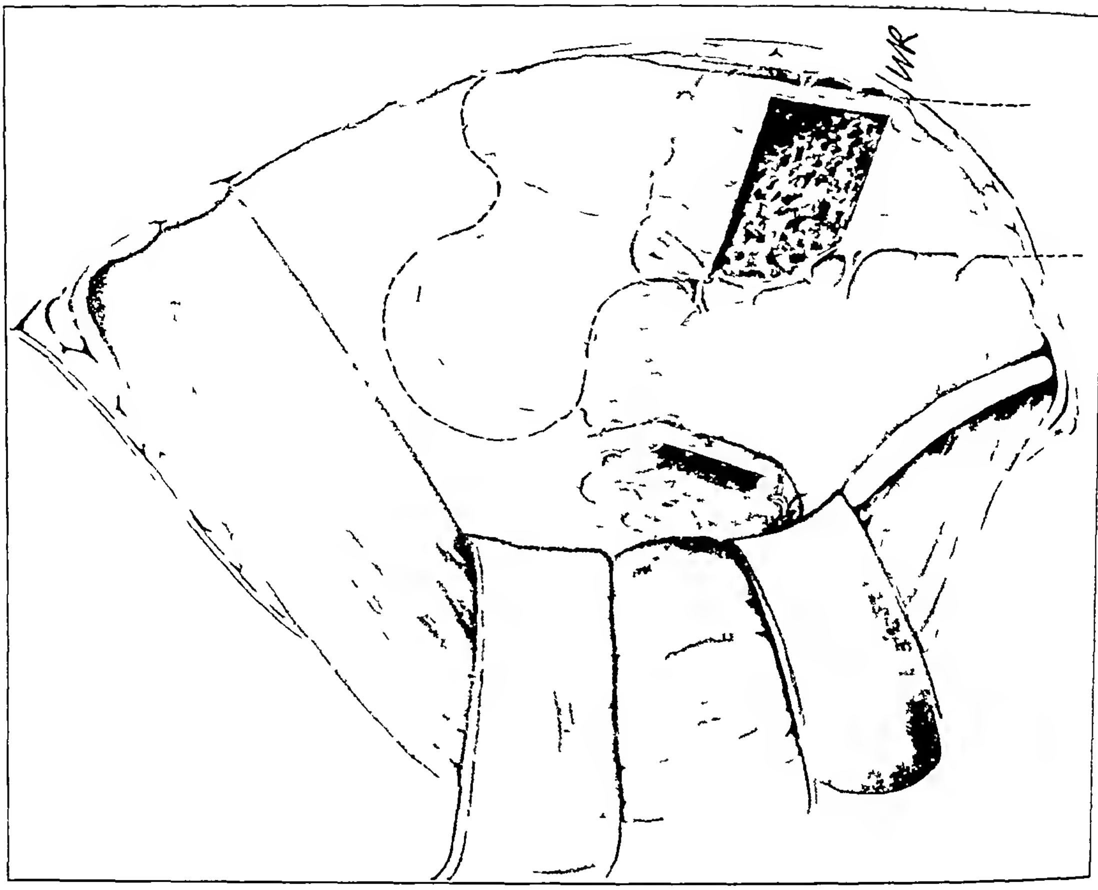
Schematic representation of the original Trumble operation. (Reproduced, by permission, from article by H. C. Trumble in *Australian and New Zealand Journal of Surgery*, 1: 417, 1932.)

PREOPERATIVE PREPARATION

Several days before the operation, the patient has a one and one-half spica cast applied, with the diseased hip held in the proper position for fusion and a dummy dressing placed over the operative field. The cast is bivalved the following day, in such a way as to permit adequate exposure of the operative field when the posterior half is removed (Fig. 2). Because the anterior half must necessarily be narrowed considerably in the region of the groin, a steel bar should be incorporated in this portion of the cast for strength. Both halves are lined with stockinette and allowed to dry thoroughly.

The day before the operation, the affected limb is prepared for surgery. The previously constructed bivalved plaster cast is applied over the sterile toweling and is worn, in order to be sure that the cast is comfortable.

* Read at the Annual Meeting of The American Orthopaedic Association, Colorado Springs, Colorado, May 18, 1949.



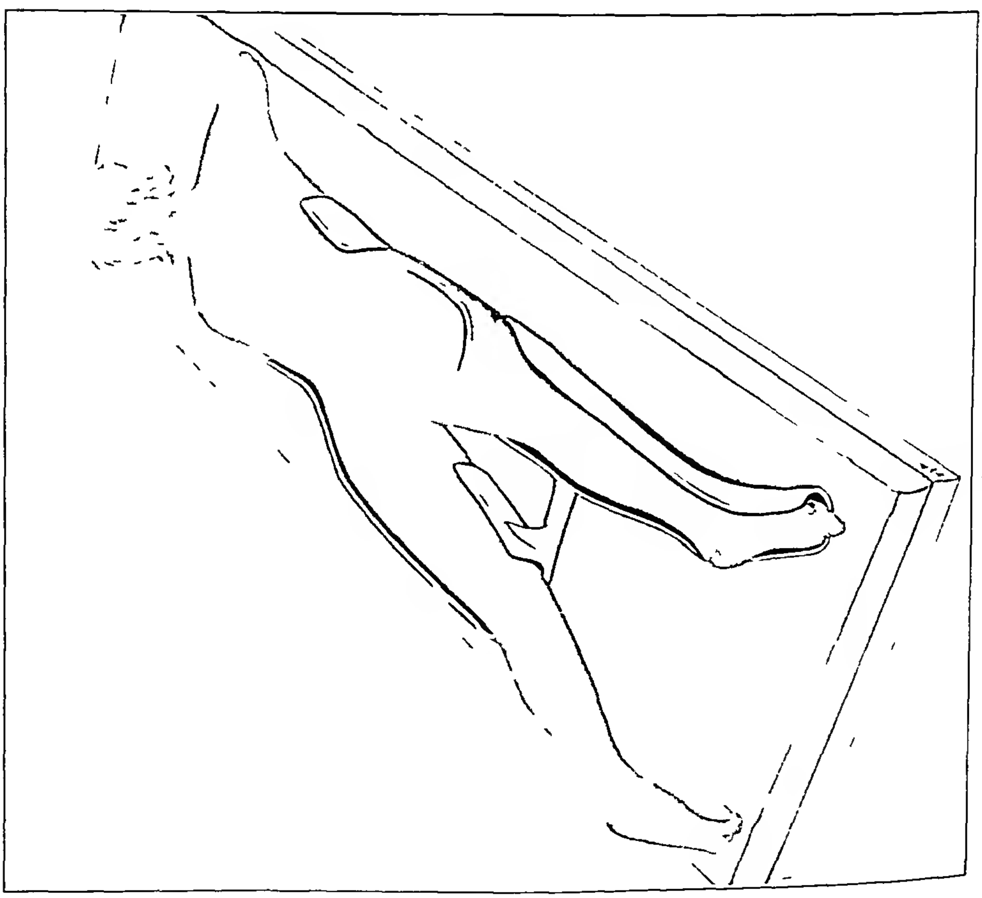


Fig. 2

Fig. 2. Position of patient on the operating table lying in the anterior portion of a bivalved plaster cast. The operative incision is shown.
Fig. 2-A. Preparation for graft.

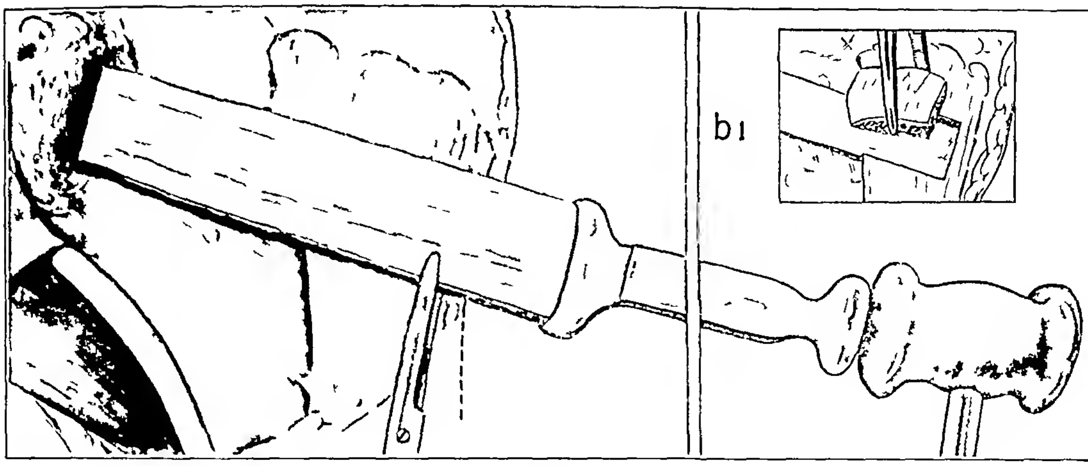


Fig 3-B
Insertion of graft into ischium Inset shows graft countersunk into femoral mortise, bone block is being replaced

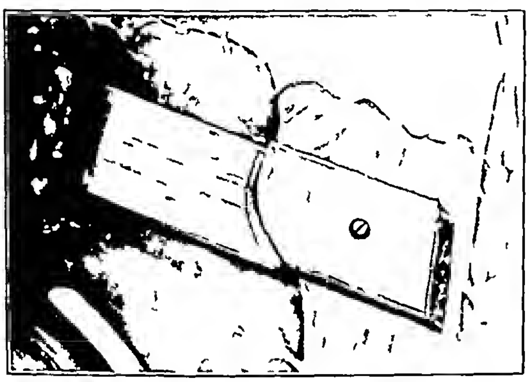


Fig 3-C
Graft has been secured in position

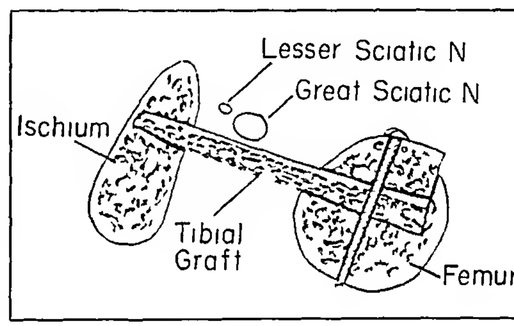


Fig 3-D
Cross section shows fixation of graft

THE OPERATION

With the patient lying face down in the anterior half of the plaster shell on the operating table, an incision is started at the tip of the greater trochanter and is carried downward and medially to a point one inch below the gluteal fold in the mid-line (Fig 2) The incision is deepened through the fascia lata to expose the trochanteric bursa in the upper portion of the wound and, a little below this, the osseous insertion of the glutaeus maximus The latter structure is most easily identified by placing the finger under the fascial insertion of the glutaeus maximus in the upper portion of the wound and dissecting distally for a short distance, the osseous insertion can be felt readily, attached to the posterior surface of the femur Once this has been located, it is completely isolated by passing any long curved instrument behind it The osseous insertion is then divided, about one-half inch from the bone, to allow for future suturing, the division is best made between clamps so as to control bleeding

When the muscle insertion has been divided, it is quite easy to elevate the remaining portion of the glutaeus maximus from the underlying soft parts by simply deepening the lower limb of the incision Caution should be observed in doing this, however, because the posterior femoral cutaneous nerve (lesser sciatic nerve) lies rather superficially, as it emerges from beneath the glutaeus maximus in the mid-line, and careless or deep dissection at the extreme lower end of the wound might injure it

The whole flap, consisting of skin, subcutaneous tissue, deep fascia, and glutaeus maximus, is rolled upward and medially, bringing into view the sciatic nerve The nerve should be clearly identified before proceeding further, but it should not be dissected from

FIG 4

Case 1 (A G), four and one-half years after Trumble operation Note the marked hypertrophy of the tibial graft Patient is well and free from symptoms, the sinus has remained healed The right sacro-iliac joint had been fused for tuberculosis, one year prior to the hip fusion

its surrounding soft parts, or handled in any way other than to be gently and carefully retracted along with the glutaeus maximus No attempt is made to separate the posterior femoral cutaneous nerve from the sciatic nerve, and both are carried on the deep surface of the glutaeus maximus while it is being drawn toward the mid-line during the remainder of the operation

The operator then palpates the tuberosity of the ischium and divides the fascial and periosteal layers overlying it, to expose the bone subperiosteally After this has been done a measurement is taken with a ruler or caliper to determine the required length of the tibial graft, as follows The distance between the ischium and the lateral edge of the femur at the desired angle is noted, and to this measurement is added an inch and a half, which will represent the amount of penetration of the graft into the ischium After the proper length has been obtained, the hip wound is covered with a sterile towel and the tibia is exposed

By flexing the knee of the limb which is being operated upon, the anterior surface of the tibia is brought into view, and from this area a full-thickness cortical graft is removed with an electric saw This graft should be the width of the entire anteromedial surface of the upper end of the tibia Its length, as just mentioned, should be one and one-half inch longer than the measured distance between the ischial tuberosity and the lateral edge of the femur, and its thickness should comprise endosteal bone from the marrow cavity, as well as the heavy cortical bone layer with its periosteum The narrow end of the graft is sharpened after removal, so that it may be driven more readily into the substance of the ischium

The leg wound is closed by an assistant, while the operator arranges for placement of the graft A window or slot is cut in the exposed cortex of the ischium, as this is done the blade of the osteotome should be flat against the shaft of the femur, so as to ensure that the graft will lie in the proper plane and fit accurately when driven into the substance

the ischium. The size of the ischial window (usually one inch by one-quarter of an inch) should correspond to the width and thickness of the tibial graft. After the window has been cut, an osteotome is driven through the opening to the opposite cortex and levered up and down several times to facilitate penetration of the graft. The sharpened end of the graft must fit snugly into the window of the ischium and, at the same time, its rough, cancellous surface must lie flat against the posterior surface of the femur, at the desired angle. The graft thus being used as a marker, a block of bone is cut from the posteromedial portion of the femur, after the overlying soft parts have been excised or retracted out of the way. The depth or thickness of this block of bone is about one-half the diameter of the femur, and care is taken not to have it include the lateral femoral cortex, which should remain intact. The block is outlined with a sharp osteotome and removed as one solid piece of bone, to be saved for future use.

The ischium and the femur have thus been prepared for the introduction of the tibial graft (Fig. 3-A). A slot has been cut in the ischium to receive the sharpened end of the graft, and a mortise has been prepared in the femur, into which the blunt end of the graft is to fit. It remains only to drive the graft into the substance of the ischium to a point which will allow its broad, blunt end to fit into the femoral mortise (Fig. 3-B). After this has been accomplished, the lateral end of the graft is countersunk into the mid-portion of the femur, the block of bone previously removed is placed on top of it (Fig. 3-B, inset) and held securely by a stainless-steel screw, which penetrates the bone block, graft, and deep femoral cortex, locking them together (Figs. 3-C and 3-D).

After the graft has been securely embedded, the retracted gluteal-muscle flap is released and the soft parts automatically fall back into anatomical position, with the

FIG. 5

Case 2 (M. L.), three years after Trumble operation. The first operation to fuse the right hip by an iliofemoral arthrodesis, in January 1946, was discontinued because of an acute tuberculous process with abscess in the superior acetabular region of the ilium. Five months later, a Trumble ischiofemoral fusion was performed. At the present time, the patient is in excellent health, is symptom-free, and her hip sinus has remained closed for three years. Note that the graft has become firmly integrated into the bony structure of the hip. The patient's lumbar spine had been fused five years prior to hip fusion.

Fig 6

Case 3 (C D), two years and ten months after Trumble operation The tibial graft has become hypertrophied, and there is solid bony union of graft and hip joint Two sinuses have remained healed since four months before operation The patient is active and well

Fig 7

Case 4 (A D), two years and seven months after Trumble operation Note that there is firm bony union between femur and ischium The patient is active and well, and all of his sinuses are closed

Fig 8

Case 5 (W F), two years and six months after Trumble operation An error in diagnosis was made in 1942, when a cup arthroplasty was performed The operation was unsuccessful and the cup was removed A diagnosis of tuberculosis was established, and iliofemoral fusion was attempted in 1943 The fusion was not successful A second attempt at iliofemoral fusion was made in 1944, this also failed and three sinuses developed The patient was then sent to Lakeville State Sanatorium, where a Trumble ischiofemoral arthrodesis was performed in November 1946 Note that graft has become hypertrophied and that the hip joint has fused During her convalescence, a tuberculous lesion was discovered in the patient's spine and a spine fusion was carried out successfully At present, she is active and well and her three tuberculous sinuses have remained healed

sciatic nerve and the posterior femoral cutaneous nerve lying superficial to the smooth cortical surface of the tibial graft The previously divided glutaeus maximus insertion is next sutured, and the wound is closed in the usual way

The posterior half of the plaster cast is then placed over the sterile dressings on both leg and hip and is attached securely to the anterior portion, in which the patient has been lying during the operation

MODIFICATIONS OF THE TRUMBLE TECHNIQUE

The foregoing description of the operation differs in a few minor respects from that originally given by Trumble For instance, he uses a posterior plaster shell for external fixation instead of a one and one-half spica cast Also, he anchors the tibial graft into the femur by a trap-door method (Fig 1), as contrasted with the metallic screw fixation which the author prefers, because it is much simpler and more secure (Figs 3-C and 3-D) Trumble also separated the posterior femoral cutaneous nerve from the sciatic nerve and placed them on opposite sides of a curved tibial graft This procedure has not been tried in the present series of cases, these nerves were carefully left undisturbed, except for gentle retraction under the glutaeus maximus Moreover, the tibial graft was a straight one, instead of curved

Finally, the sound limb, as a rule, was selected by Trumble to supply his tibial graft, whereas the writer has felt that it is unwise to involve the sound leg, unless absolutely necessary Sometimes, because of a marked decrease in size of the affected limb or the presence of local disease, the sound side will provide a healthier and larger tibial graft In such instances, of course, the good leg should be used

TABLE I

SUMMARY OF DATA IN SEVEN PATIENTS

Case No	Patient	Age and Sex	Duration of Disease	Associated Lesions	Recumbency after Operation (*Months*)	Follow up Duration	Follow up Result
1	A G	43 F	2 yrs, 9 mos	Tuberculosis of right sacro-iliac joint, sinus in right upper thigh	6	4 yrs, 6 mos	Fusion
2	M L	38 F	2 yrs, 6 mos	Tuberculosis of spine, pulmonary tuberculosis, lateral hip sinus	6	3 yrs	Fusion
3	C D	17 F	3 yrs, 5 mos	Two sinuses in groin	6	2 yrs, 10 mos	Fusion
4	A D	15 M	7 yrs, 5 mos	Three sinuses,—lateral portion of hip, abdomen, and groin	6	2 yrs, 7 mos	Fusion
5	W F	24 F	5 yrs, 2 mos	Tuberculosis of spine, three sinuses in lateral portion of hip	13	2 yrs, 6 mos	Fusion
6	L D	32 M	3 yrs, 4 mos	Sacro-iliac and pulmonary tuberculosis, three sinuses in anterior, medial, and lateral portions of thigh	8	1 yr, 7 mos	Fusion
7	L N	41 M	1 yr, 7 mos	Pulmonary calcaneal nodes, sinus in lateral portion of hip	6	1 yr	Fusion

DISCUSSION

There are three or possibly four contra-indications to the Trumble operation, which are self-evident

1 When marked deformity of the hip exists, resulting in a wide separation of the ischium and femur,

2 When active disease is present in the ischium or the subtrochanteric region,

3 When draining sinuses are present in the posterior portion of the hip and thus contaminate the operative field

4 Another possible contra-indication may be when the head of the femur is dislocated or has no firm contact with the acetabulum or ilium

It should be remembered that this operation is applicable only for hip joints that preoperatively are in a proper position for fusion and weight-bearing It is in no sense a procedure to correct deformity, but is intended only to fuse and consolidate the bony structures in the position where they already are

During the time that the author has been employing the Trumble operation for tuberculosis of the hip, many questions have arisen, such as

1 Can the operation be done at an early stage of the disease while the condition is still acute, thus preventing the possibility of excursion of the femoral head or neck upward on the blade of the ilium?

2 Now that streptomycin is available, need one wait for subsidence of acute symptoms before carrying out this type of surgery?

3 For how long a period of time is external immobilization necessary following the Trumble operation? How much protection is actually required after operation? When should weight-bearing be started?

4. Does the diseased area of the hip joint, *per se*, heal or fuse after this operation? If so, how long does it usually take?

5. How important is the angle at which the graft is placed? Does this influence the time of healing of the tuberculous process? Does it affect the final result?

6. Is hypertrophy of the tibial graft mainly the result of adductor-muscle pull or of weight-bearing?

These and many other questions will be answered in the course of time, as our experience grows. At present, all the writer can say from personal knowledge is that, given a proper selection of cases in which the hip disease is quiescent, and a sufficient period of postoperative protection (an average of six months) in a plaster cast, the Trumble operation has proved more successful than any other form of extra-articular arthrodesis of which he knows.

As far as we can tell from the patients operated upon, not only does the graft remain alive and fuse, but the disease also tends to heal. Fusion of the joint itself evidently requires a much longer period of time, and will depend largely upon the extent and character of the disease process.

From our experience with this operation, it does not seem to be of vital importance whether the graft is placed at a right angle to the shaft of the femur or more in line with its weight-bearing force. No one rule has been followed in the placement of our grafts as far as angulation is concerned, and yet all have healed well and all have become hypertrophied. Theoretically, those grafts which are placed more in the line of weight-bearing should become hypertrophied to a greater degree, at least until healing of the disease takes place. Nevertheless, we find that graft hypertrophy takes place in some instances before any weight-bearing is started.

FIG. 9

Case 6 (L. D.), one year and seven months after Trumble operation. Note hypertrophy of the tibial graft. One year after operation, the patient fell downstairs and fractured the tibia and fibula of his affected leg, without disturbing the ischiofemoral graft. He is now active and well and all three sinuses have remained closed. His right sacro-iliac joint had been fused three years before the hip fusion.

FIG. 10

Case 7 (E. N.), one year after Trumble operation. Note presence of tuberculous disease in greater trochanter as well as in acetabulum. This was present before operation. The graft has become hypertrophied to a greater extent at the ischial end, but seems to be solid also at the femoral attachment. Clinically, fusion is solid and the hip is painless.

In all probability, this is due to adductor-muscle pull. Could it not be, then, that the tibial graft is influenced by both forces, and that early hypertrophy of the graft is due to adductor influence and late hypertrophy to weight-bearing?

If neither tibia is suitable for supplying a bone graft, either because of local disease or some other cause, it is quite easy to retract the thigh muscles of the operative hip wound and to take a graft from the femur, just distal to the prepared mortise. The author has done this successfully in a patient whose prepared tibia was underdeveloped and, therefore, not suitable as a donor site.

SUMMARY

Thirteen patients with tuberculosis of the hip joint have been treated at the Lakeville State Sanatorium, by the Trumble operation. Of these, seven had their operations more than one year ago and have solid bony fusion (Table I). The remainder have not been treated sufficiently long for a final end result. All of the patients are doing well, however, and the outlook for successful fusion is excellent. So far, there have been no failures and only two complications.

One complication concerned a tibial graft which slipped out of the window in the ischium, because the graft had been cut too short. This was a technical error in measurement, and the graft did not penetrate into the substance of the ischium. A graft of greater length, taken two weeks after operation from the opposite tibia, was used to replace the dislocated one. Instead of discarding the short graft, it was put into the bed of the tibia from which the longer graft had just been removed. Healing progressed favorably after the second operation.

The second complication had to do with a small pressure area over the head of the fibula, produced by the plaster leg cast, which caused a transient peroneal palsy. A window was cut in the cast to relieve this pressure, and the signs of paralysis soon began to disappear. Full recovery resulted.

Roentgenograms of the seven patients whose operations were performed a year or more ago are shown (Figs 4 to 10, inclusive)

CONCLUSION

While the small number of cases reported in this paper do not warrant any infallible conclusions, and the report should be considered preliminary, yet the writer is convinced that the Trumble type of ischiofemoral arthrodesis is the best form of extra-articular fusion for the hip joint that has yet been devised In his opinion, it should be used more extensively

NOTE Since the presentation of this paper, three additional cases have been followed up at a period of one year after operation All show solid, bony fusion making a total of ten successful cases to date

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A TECHNIQUE FOR ARTHRODESIS OF THE HIP JOINT*

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Arthrodesis frequently is difficult to accomplish in osteo-arthritic hips The bone is sclerotic and relatively avascular, and the capsule and synovial membrane usually are thickened and fibrotic The patients often are obese, and effective immobilization in a plaster spica is difficult or impossible Therefore, internal fixation by some form of metal has been found advantageous in these operations A method of driving multiple square nails from the ilium into the femoral head and neck has been evolved, this method has been successful in a small series of cases, and it is believed that it offers certain advantages in some of these operations

* Read at the Annual Meeting of The American Orthopaedic Association, Colorado Springs, Colorado, May 18, 1949

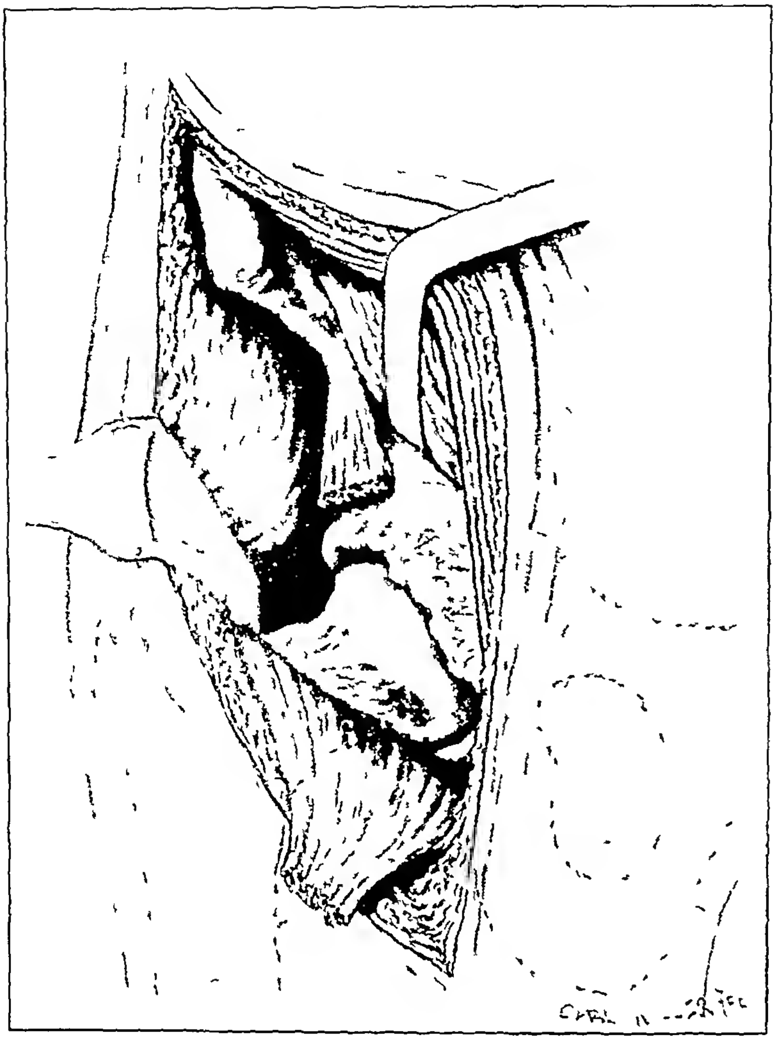

FIG 1

Exposure of hip joint The quadriceps is detached from the anterior inferior spine of the ilium, and not at the point indicated

The method was first used in a modified form in 1943, in an operation on an obese woman, fifty-two years old, who was to have had fusion of the left hip because of painful osteo-arthritis The joint was exposed by a Smith Petersen incision and the intention was to use an iliac graft, after removal of the cartilage from the superior portion of the head and acetabulum Before this could be done, however, the patient's condition became bad, and it was deemed wise to terminate the operation as soon as possible A wide osteophytic lip protruded from the upper margin of the acetabulum and Robert J Neville, who was assisting, suggested that two square nails be driven through this, into the femoral head This was quickly done and, after closure of the incision, the patient was returned to bed without any form of external fixation being applied At the end of twelve weeks, the fusion appeared to be solid enough to permit her getting up The fusion has remained firm and the pain in her hip has been relieved

The success in this case suggested further use of the method The technique has been modified, however The capsule of the hip is exposed as widely as possible through a Smith-Petersen incision (Fig 1), as for a cup arthroplasty Care is taken to dissect the overlying gluteal and psoas muscles as widely as possible from the capsule, the superior and antero-inferior portions of the capsule are *completely* excised This is considered an important step in the operation Not only does it afford an excellent exposure of the joint but it achieves direct contact of vascular muscles with the area in which bony union is sought, in place of the thick, fibrous, relatively avascular capsule

The femoral head is then dislocated, and the remnants of articular cartilage are removed from the head and the acetabulum No attempt is made, however, to remove all of the sclerotic bone Good contact should be retained between the head and acetabulum, and, if much bone were removed, this would not be possible Numerous holes are drilled in the head and surface of the acetabulum, in order to facilitate the growth of blood vessels into the area The head is then replaced

In exposing the joint, the rectus and psoas muscles are separated The psoas and iliacus are carefully stripped from the inner surface of the ilium, the inner wall of the anterior portion of the acetabulum thus being easily exposed The hip is placed in the

desired position,—usually about 25 degrees of flexion, neutral rotation, and little or no abduction. Two square Vitallium or stainless-steel nails with flat, rounded heads are driven from within the pelvis through the acetabulum, into the head and neck of the femur. One of the nails should be long enough (about three and one-half inches) to traverse the greater part of the neck. It is better to introduce the nails in slightly different directions, so that they are not parallel. If there is an osteophytic lip on the superior rim of the acetabulum, as often is the case (Fig. 2-A), a similar but shorter nail is driven downward through it, to transfix the head in a vertical direction. Thus three nails traverse the ilium and femur in different planes, so that fixation of the head is very firm (Figs. 2-B and 2-C).

Closure of the muscles over the ilium is greatly facilitated by removing a strip of bone, an inch or so in thickness, from the iliac crest. Some of this bone can be used to good advantage in packing around the margin of the acetabulum. No effort is made to place bone inside the acetabulum, because this would disturb the even contact which has been obtained between it and the head.

The wound is then closed in layers. A plaster spica may be applied or not, as seems fit. In several of the authors' cases it was omitted, and it is believed that it would be safe to do so in most instances. The period during which the patient is kept in bed has varied from two or three to twelve weeks. Early ambulation should be possible in an increasing number of cases.

The technique has been designed especially for osteo-arthritic hips. It has been used in other conditions, such as arthritis following congenital dislocation or subluxation, and suppurative arthritis. It is not recommended in cases of tuberculosis, or when there is likelihood of a pyogenic infection becoming reactivated. In some cases the technique has been modified by the use of two instead of three nails, and by introducing all of them into the pelvis from without. Although this has succeeded in a few cases, it is not considered as good as the method described here. The nails driven from within have a firm hold on the ilium, even though they penetrate its thinnest portion, which is not true of those which are driven in from without.

Up to November 30, 1948, fourteen patients, eight females and six males, were operated upon by the technique described. Their ages varied from ten to sixty-four years, the average age of the males being forty-nine, and that of the females thirty-six and one-half years. Fusion resulted in twelve cases. In two, solid union failed to develop after seven months, and the results must be classed as failures. One of these patients had had two previous attempts at arthrodesis by other methods, there was a large amount of scar tissue around the joint, and the bones were very sclerotic. In the other case, with aseptic necrosis of the femoral head following fracture, the mistake was made of removing too much bone from the femoral head and acetabulum, thereby diminishing the area of contact.

In five other cases two or more nails were used, but otherwise the technique varied considerably from that described, making these cases unsuitable for inclusion in the series. Solid fusion was achieved in four. In the one failure in this group, the cartilage was removed only from the upper portion of the head and acetabulum. A bone graft was placed along the upper surface of the neck and head, penetrating the acetabulum, but without fixation in the ilium. When a second operation was done on this patient, it was found that one of the intrapelvic nails had become loose and had protruded a slight distance into the pelvis. It was removed without undue difficulty.

In two patients in the series of fourteen, pulmonary infarction developed after operation, presumably from thrombophlebitis. Both patients recovered. Philip Wilson noted several cases of thrombophlebitis after hip-fusion operations in which a Smith-Petersen nail had been driven through the head and neck of the femur from inside the ilium, and suggested that the separation of the iliacus muscle from the inside of the pelvis

FIG. 2-A

FIG. 2-B

FIG. 2-C

Fig. 2-A: Osteo-arthritis of the hip, with a projecting ledge of bone.
Figs. 2-B and 2-C: Anteroposterior and oblique views after insertion of nails, two from inside the ilium.

Fig 3-A

Fig 3-B

Fig 3-C

Fig 3-A Osteo-arthritis of hip joint, probably resulting from congenital subluxation
Figs 3-B and 3-C Anteroposterior and oblique views with nails in place

might predispose to this condition. In our experience, however, this has not happen after arthroplasties, in which the iliacus is similarly elevated from the pelvis.

DISCUSSION

DR. CARL E. BADGLEY, ANN ARBOR, MICHIGAN: It is a great privilege to have the opportunity to disc these two excellent papers. We have here the problems Dr. Smith has brought up, of extra-articular fu for osteo-arthritis and for tuberculosis, and of intra-articular fusion for osteo-arthritis.

I must confess a complete ignorance of the Trumble procedure. As far as I am concerned, this wou be known as the Van Gorder operation. However, it is based on the principles that Brittain utilized. We a familiar with the results of the Brittain operation. Dr. Van Gorder's operative technique has been beautiful presented by the motion picture. Technically, it surpasses the Brittain procedure, and it is one that we w all readily adopt, whereas I have been hesitant to adopt the Brittain procedure, with its method of bli insertion of the graft. I think the visualization of the fragments, made possible, will be employed not only f the procedure that we have seen today, but for a number of other conditions. I have utilized a similar ap proach for subtrochanteric fractures, the glutaeus maximus attachment to the linea aspera being used as guide to the displaced lower fragment of the femur, without any muscle being traversed or sectioned. I hav been able to get complete reduction very readily in a badly displaced fracture.

I can see where Brittain's type of complete osteotomy may be utilized by Dr. Van Gorder in cases whe there are deformities of the hip. In his paper he emphasized that the Trumble operation is not applicable i case of deformity. Only when there is proper position can you utilize his operation. However, I can concei of doing a transverse osteotomy by his approach, correcting the deformity, and utilizing a graft very muc akin to Brittain's method, by this surgical approach that Dr. Van Gorder has presented.

I have been very much impressed with the similarity of the roentgen appearance of the hip joint fo lowing Brittain's procedure and Dr. Van Gorder's procedure. The head of the femur and the trochanter hav undergone marked osteoporosis in all Dr. Van Gorder's cases, showing something that I think is most im portant in the consideration of the value of the extra-articular operative procedure over the intra-articula procedure in tuberculosis of the hip. There is obvious evidence, by the marked atrophy which has occurre in the structures above the graft, that the graft immediately relieves all pressure and all weight bearing i the hip joint itself. The architectural principle, as Brittain has called it, of the dome taking the stress ar strain over onto the ischium, must be of great value in the healing of the tuberculous process.

The surgeon need not fear operative exposure of a tuberculous joint any more in the hip than he does the knee. We developed a relatively simple operative procedure in 1929 for tuberculosis of the hip. We remo the crest of the ilium, split the anterior part of the ilium to the acetabulum and open it up widely like a boo then turn the excised fragment of the whole cortex of the ilium about 180 degrees. The proximal porti becomes the distal portion, so that the natural curve of the iliac crest allows it to fit into a prepared slot i the intertrochanteric region and head and neck of the femur, then it is thrust into the leaves of this separate ilium and held securely in position by the automatic compression of the separated iliac halves. We also d an intra-articular removal of cartilage in disease without dislocating the hip. However, we have had to wa for a period when the lesion was quiescent and, for many cases, this was a number of years. It seems to m that Dr. Van Gorder's operation could be done without the long period of waiting which we have had i our cases.

Incidentally, the results of our arthrodeses in tuberculosis and the results reported by Dr. Alan Smi in a previous paper on tuberculosis were 66 per cent. The results of those reported by Dr. Van Gorder w 100 per cent. So I must say I am a convert to the principle of extra-articular fusion by Van Gorder's meth in tuberculosis of the hip, and possibly in many other conditions, when you do not want to run the dang of lighting up the infection.

I am sorry time does not permit discussion of Dr. Smith's paper.

DR. ALBERTO INCLÁN, HAVANA, CUBA: Fusion of the hip is frequently discussed, due to the fact th none of the numerous operations devised for this purpose is entirely satisfactory.

The papers presented by Dr. Van Gorder and Dr. Alan Smith are proof of the preceding statem Dr. Van Gorder has offered the results of his experience with the revival of a little-known operation extra-articular hip fusion,—namely, Trumble's ischiofemoral arthrodesis, while Dr. Smith has present new technique for intra-articular fusion of the hip, involving intrapelvic nailing of the iliac bone to t head of the femur.

In reference to Dr. Van Gorder's paper, ischiofemoral arthrodesis, with a bone graft to bridge the gap be tween ischium and femur, was used long before Trumble published his first paper in 1932. Maragliano reported this technique in 1919. The Trumble operation appears to be a much more elaborate procedure th Brittain's technique for ischiofemoral fusion. The latter procedure has been employed by Dr. Inclán on my Service for the past two and one-half years, in children, adolescents, and adults.

In the copy of Dr. Van Gorder's paper, which he kindly forwarded to me, no statement was ma

cerning the ages of the various patients operated upon This we consider of importance, since the percentage of fusions obtained is considerably lower in children, regardless of the technique used We have also found that proper placement of the graft obliquely from below upward, and internal displacement of the femoral shaft, shortening of the gap between femur and ischium, and suppressing the sheering effect of weight-bearing, are conducive to solid fusion, with secondary hypertrophy of the graft We have employed Brittain's technique, with certain modifications, in sixteen cases Although favorably impressed by it, we feel that we need more cases and a longer follow-up period before rendering any conclusions However, we consider Brittain's technique preferable to Trumble's, because of its simplicity and the fact that a medial displacement of the weight-bearing line occurs, due to the internal shifting of the femoral shaft At the present time we consider it the operation of choice for the extra-articular fusion of tuberculous hips

In discussing Dr Alan Smith's paper on intra-articular fusion of the hip for osteo-arthritis and similar conditions, I congratulate him on being able to nail those hips from within the pelvis It seems to me a major procedure, involving extensive dissection of articular and periarticular tissues The reflection of the iliacus muscle may explain the relatively high incidence of thrombophlebitis which he has reported

In the type of case described by Dr Smith, we have been employing a combined surgical procedure, securing fixation by a long Smith-Petersen nail driven through the neck and head of the femur high into the ilium (as advocated by Watson-Jones), and depending for fusion on a sliding graft, taken from the outer cortex of the ilium, and placed between the ilium and the greater trochanter

A Vitallium screw holds the end of the graft firmly in apposition with the raw surface of the iliac bone, just proximal to the rim of the acetabulum The articular capsule may be excised, and the graft placed in direct contact with the freshened superior surface of the head and neck of the femur This technique has given satisfactory results in the limited number of cases in which we have employed it No postoperative plaster-cast immobilization is utilized, and the patients may be up in wheelchairs a week following operation and may walk on crutches four weeks afterward

I congratulate the authors for their excellent contributions to the solution of the difficult problem of hip fusion

Dr Van Gorder (closing) I want to thank Dr Badgley and Dr Inclán for their kind criticisms of my paper, and to make one correction regarding the chronology of the Trumble operation

It is not a more recent operation than the Brittain procedure, as was implied by Dr Badgley, but was performed nine years before the Brittain operation In fact, Brittain himself stated in his book (Architectural Principles in Arthrodesis, Baltimore, Williams and Wilkins Co , 1942) that his hip operation was based on the "ingenious ischiofemoral arthrodesis" of Trumble

The Trumble operation differs fom the Brittain operation, however, in two important respects (1) The femur is not osteotomized and (2) the operation is not blind

If the Trumble operation is successful in fusing the hip, as it appears to be, the thought must surely arise Why is it necessary or wise to go to the trouble and danger of fracturing the patient's femur in order to establish a bony ridge between the ischium and the femur, when this same end can be accomplished much more accurately, much more safely, and with much less trauma by the operation here described?

The extent of trauma associated with the Brittain procedure apparently varies considerably, as is natural in any blind procedure For instance, Brittain quotes McMurray as stating that there is more shock after the Brittain operation than after any other method of arthrodesis Although Brittain himself states that just the opposite is true, nevertheless he has written (J Bone and Joint Surg , **30-B** 642–650, Nov 1948) "Some oozing always takes place, and sometimes it may appear alarming If the anterior pelvic brim is traversed, the obturator artery may be divided In addition, one may divide branches of the lateral femoral circumflex artery taking part in the digital anastomosis, and there may be muscular oozing from dividing the iliopsoas and small muscle like the piriformis and obturators None of this haemorrhage is serious, with the possible exception of that from the obturator artery in a debilitated patient There is no doubt that oozing does take place and that it goes on after operation, so that it is wise to have blood transfusions readily available " If one adds to the arteries mentioned above that may be divided, the external iliac, which is known to have been perforated while this operation was performed, then the danger of working in the dark amid important structures, including the sciatic nerve, is all the more impressive

One is forced to question seriously, therefore, the advisability or the justification of carrying out an ischiofemoral fusion of the hip blindly, when a successful open procedure is available

SLIPPING OF THE UPPER FEMORAL EPIPHYSIS *

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From the New York Orthopaedic Hospital, New York City

A study of seventy cases of slipping of the upper femoral epiphysis from the New York Orthopaedic Hospital was presented in 1931[1]. Sixty-two additional cases, a total of 132, were presented in 1941[2]. From 1941 until January 1947, 111 additional cases have been treated, a total of 243. A careful and complete analysis of these cases forms the basis for the following report.

PATHOLOGICAL FINDINGS

One hundred and sixty-nine hips were operated upon in various stages of the disease and gross and microscopic studies of the pathological tissue were made. Sections from the synovial membrane, the periosteum and bone of the proximal portion of the neck, the epiphyseal disc, and the femoral head were studied.

In the *preslipping stage*, grossly the synovial membrane is swollen, oedematous, and hyperaemic, and there is villous formation. Similar, but milder, changes occur in the periosteum and capsule. No gross changes are seen in the head or acetabulum. Microscopic sections of the synovial membrane disclose oedema and hypervascularity, usually with perivascular lymphocytic infiltration, scattered plasma cells and wandering cells and villi. Decalcification and hypervascularity are present at the junction of the neck and the epiphyseal disc.

In the *slipping stage*, the epiphysis is displaced downward and backward in relation to the femoral neck. Usually the epiphysis rotates into a varus position at the same time, but a valgus deformity was present in three hips. The slipping may be sudden or gradual, and often it occurs several times in succession. The epiphysis never becomes completely separated from the neck, but remains attached by periosteum and fibrous tissue, which grow over the exposed portion of the neck as the slipping occurs. This new tissue may be recognized by its bluish color, its softness and looseness, and the frequent presence of tiny islands of bare bone. The cartilaginous epiphyseal disc remains attached to the head, but is gradually absorbed and transformed into bone. Callus rapidly forms in the angle between the head and neck inferiorly and posteriorly, but is covered by a fold of hyperplastic and redundant synovial membrane. The articular cartilage of the head and acetabulum remains normal in appearance. There is rarely hemorrhage into the joint unless there has been violent manipulation. Microscopically, the soft-tissue changes are similar to those seen in the preslipping stage. There is separation between the epiphyseal disc and the neck, with degenerative changes in the disc cartilage and evidence of repair at the junction.

In the *healing stage*, the medial margin of the neck, exposed anteriorly and superiorly by the slipping, gradually becomes rounded; in addition, the callus inferiorly becomes incorporated with the neck, thus changing the contours of the neck. The epiphyseal disc is gradually absorbed, and bony union occurs between the epiphysis and the neck. The synovial membrane and periosteum become less vascular and oedematous, more scarred and inelastic. The inflammatory process usually subsides after several months, but spontaneous union of the epiphysis may require two or three years. If the head has been separated from the neck in the course of treatment, degenerative changes in the head are the rule.

In the *residual stage*, the lesion is healed and the epiphysis is solidly united to the r-

* Portion of paper read at the Joint Meeting of The American Orthopaedic Association, The British Orthopaedic Association, and The Canadian Orthopaedic Association, Quebec, Canada, June 3, 1948.

FIG 1

Section of synovial membrane (× 50), taken at operation for pegging an epiphysis in the preslipping stage Oedema, hypervascularity, villous formation, and a few plasma cells and small lymphocytes are visible

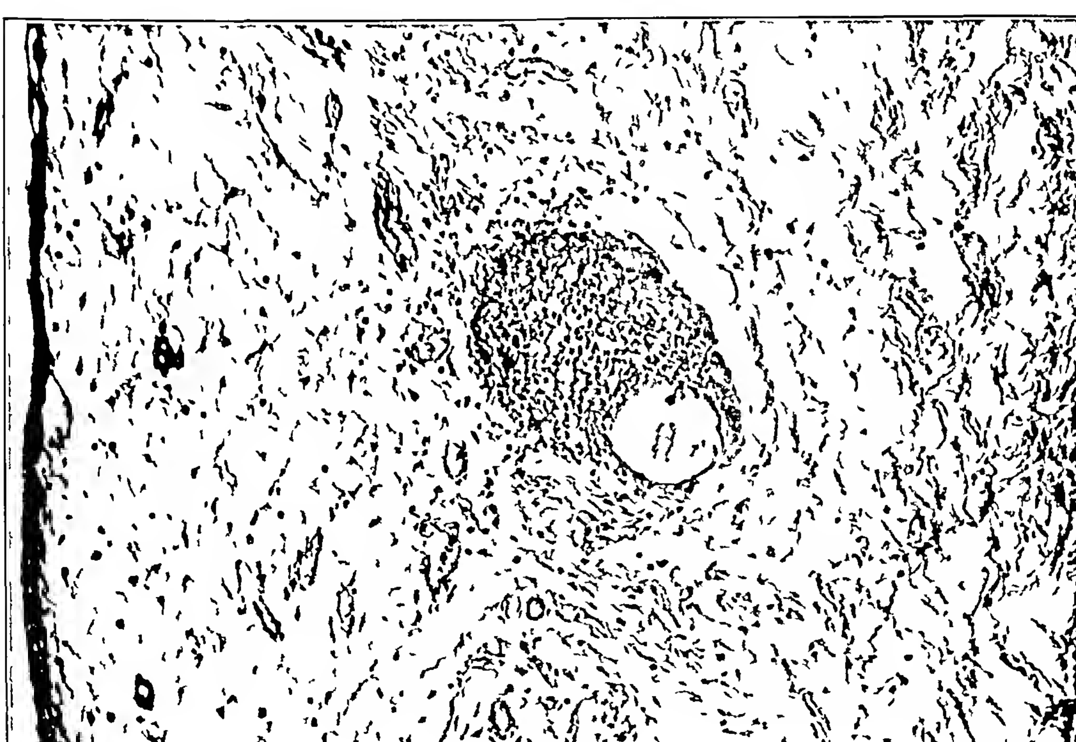

FIG 2

Section of synovial membrane (× 100), taken at operation for pegging an epiphysis in the preslipping stage Shows marked oedema and hypervascularity, with perivascular lymphocytic infiltration

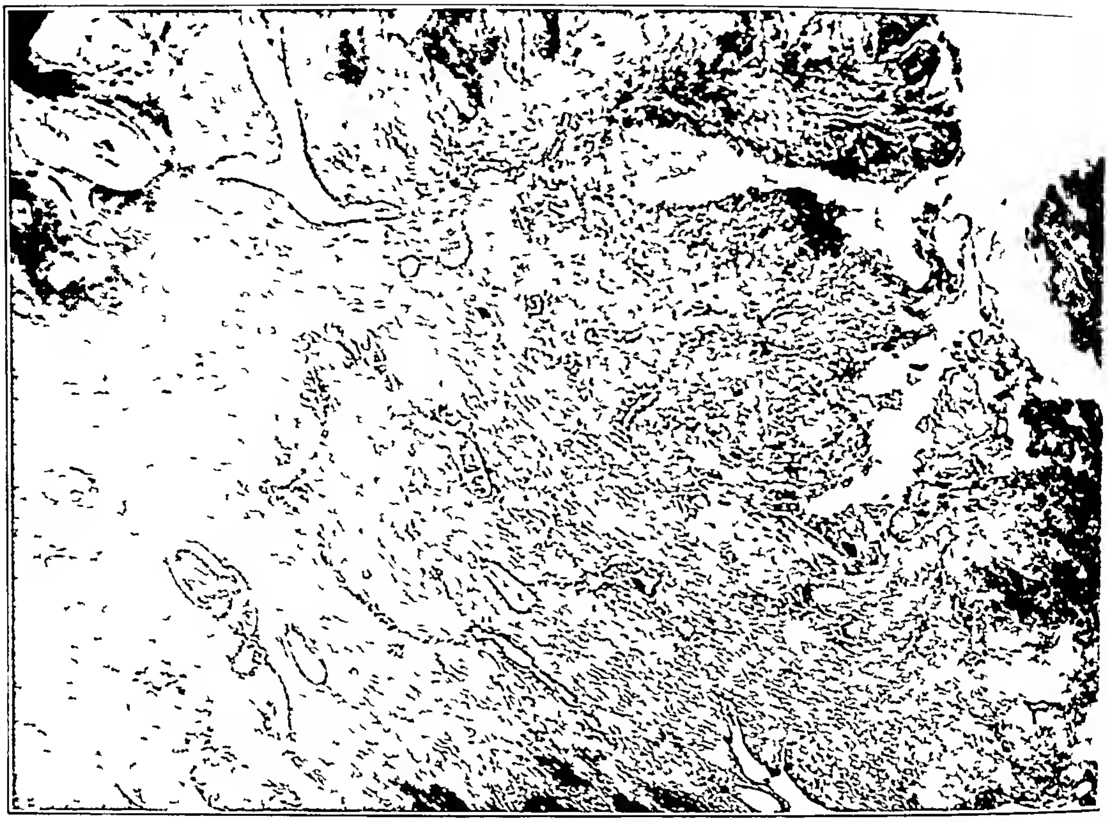

Fig 3-A

Section taken from right epiphyseal plate (× 38), at operation for pegging an epiphysis in the pre-slipping stage Shows degeneration and necrosis of fibrous tissue and cartilage

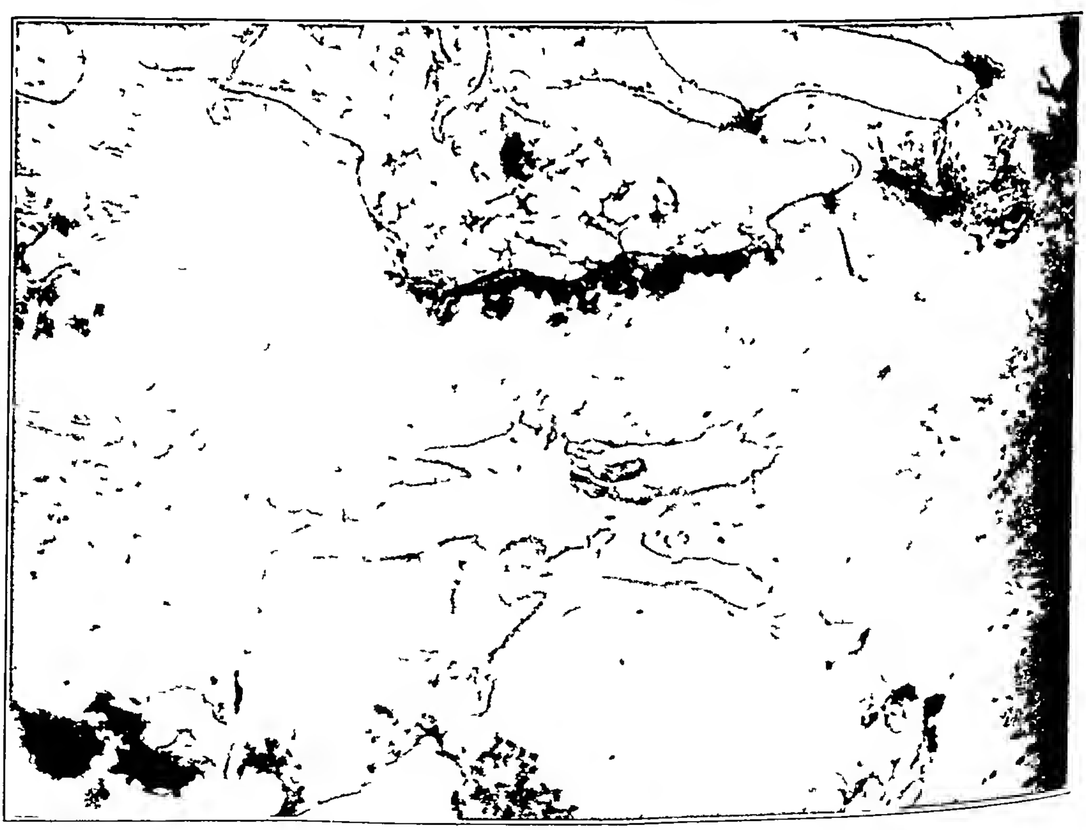

Fig 3-B

Section taken from left epiphyseal plate (× 38), at operation for pegging an epiphysis in the pre-slipping stage Degeneration, necrosis, and repair of fibrous tissue and cartilage are seen, with hemorrhage and foreign-body giant cells

FIG 4-A

Section of synovial membrane (× 100), taken at operation for open reduction of slipped epiphysis Villi are present with focal lymphocytic infiltration, oedema, and hypervascularity

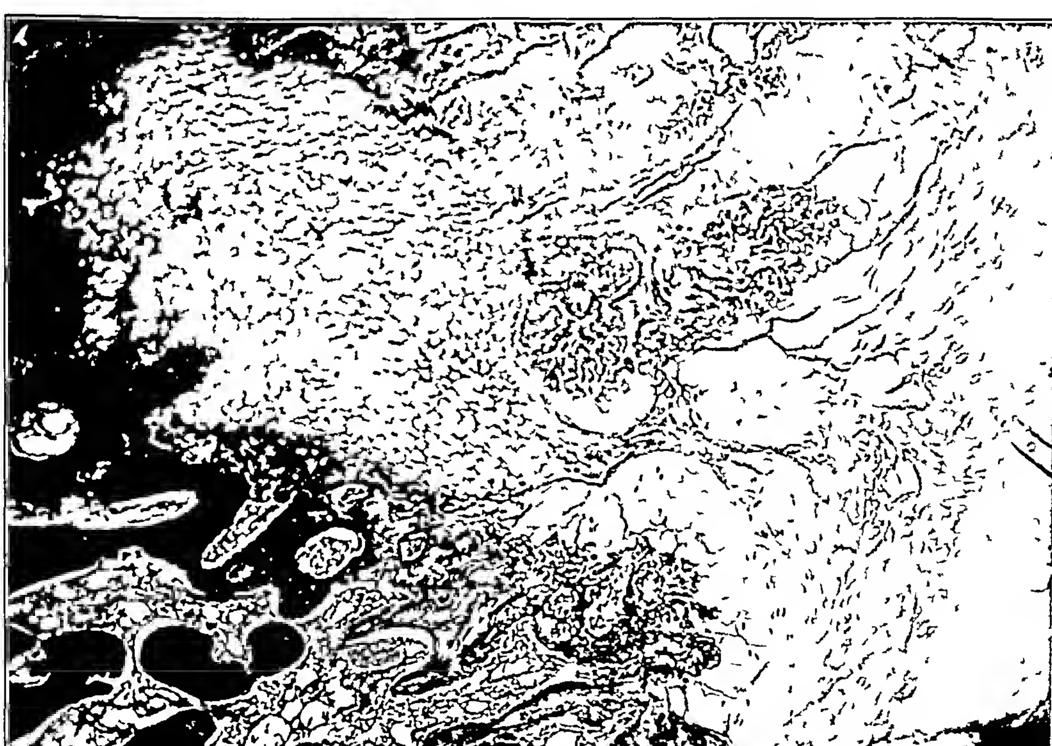

FIG 4-B

Section of epiphyseal plate of same hip (× 38) Process of degeneration and repair can at junction of plate with femoral neck, a mass of young cartilage cells is growing into a defec - cent bone

in the displaced position The callus has become mature bone, indistinguishable from tl neck itself, and the contours of the neck are smoother The synovial membrane, the per osteum, and the capsule are sclerotic and inelastic Osteo-arthritic changes develop if the is deformity, because of the faulty joint mechanics, especially if the joint is subject to strenuous activity or if there has been much damage to the circulation Osteophytic production is often seen at the margin of the head and at the margin of the acetabulum

TREATMENT

The results of the treatment for slipping of the upper femoral epiphysis should b

Fig 5-A

C , a boy, aged thirteen years, had had pain and limp for one month A bilateral pegging operation was done in the preslipping stage An excellent clinical and roentgenographic result was obtained, with no degenerative changes,—the usual result after this operation

On May 27, 1941, the epiphyseal lines were wide and irregular, with decalcification on the distal side The capsules were swollen

Fig 5-B

June 3, 1941 In lateral views, very slight posterior displacement is seen Pegging operation on l was done June 9, on right, October 20

FIG. 5-C

Roentgenogram of right hip taken October 25, five days after operation, that of left hip taken August 11, nine weeks after operation

FIG. 5-D

In lateral views taken on December 15, the epiphyseal lines had healed and were closing. The pegs were beginning to become absorbed. The heads and necks appeared healthy.

strictly evaluated in terms of the normal hip as to symptoms, signs, and roentgenographic appearance. The lesion always heals spontaneously, and treatment is of no value unless it produces a better result than would have been accomplished by nature. Too many reports of the results of treatment of this disease have failed to take these facts into consideration. The results in many cases which had no treatment have been better than those in similar cases after operation.

No Therapy

Although the lesion always heals, from one to three years are usually required and

there is the risk of considerable slipping, with deformity and its accompanying symptom and eventually osteo-arthritis However, after healing, the symptoms and signs produc by the deformity are often found to be only slight and the disability negligible unt osteo-arthritis develops in middle life

Endocrine Therapy

Thyroid has no appreciable effect on the lesion, and should be used only if there definite hypothyroidism Healing of the lesion and closure of all the epiphyses may b hastened by the administration of gonadal hormones, but limitation of growth and telescoping of adolescence will result, with the possibility of disastrous psychologic effects

Bed Rest

The disease heals as a result of rest in bed, but many months may be required Th author has seen slipping occur after six months of bed rest Slipping occurred in one boy hip when he wrestled with his brother, while in bed Bed rest or the avoidance of weigh bearing must be continued until the lesion is completely healed After all pain and spa have subsided, crutches may be used until the condition has fully healed, if the child ca be trusted to avoid weight-bearing An ankle sling attached to a Sam Browne type of bel may be used for suspending the leg, as in coxa plana, but the child with slipping of th epiphysis is often so large and the leg is so heavy that this method may not be practica

Cast or Brace

Immobilization in a plaster cast or a brace is followed by relief of pain and spa and eventual healing of the lesion, but the period of healing may be several month even two or three years, and there is considerable residual limitation of motion If a bra is used, it should be of the non-weight-bearing type, with the affected extremity suspend in the brace and a built-up shoe worn on the opposite side, and it should be removed dail for active motion with the leg supported Exercises in the pool or tank may be given late

FIG 5-E

On January 12, 1942, seven months after operation on left hip and three months after operatio right hip, the epiphyseal lines had closed and the pegs were being absorbed The heads and neck w healthy

FIG. 5-F

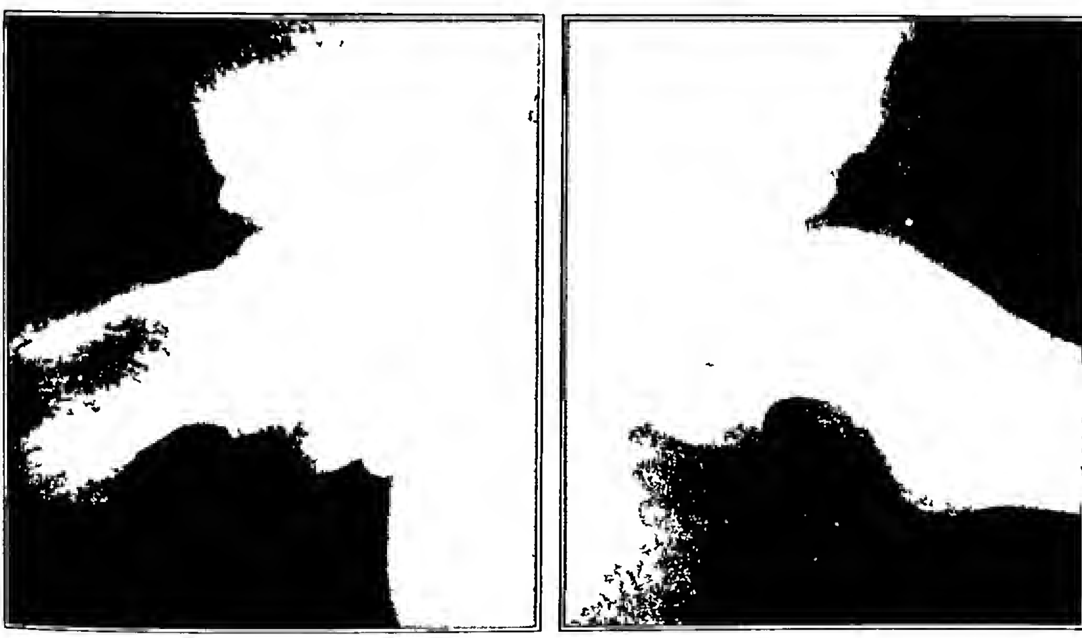

FIG. 5-G

By January 3, 1946, four and one-half years after operation, the epiphyseal lines had been obliterated and the pegs had been absorbed. The heads and necks appeared healthy. At this time displacement was negligible and there were no symptoms. The index of motion was 95.

Pegging Operation

The ideal treatment is to prevent slipping of the epiphysis and to hasten healing of the disease by the method which is simplest, safest, and quickest. For this purpose we have used, since 1930, an operation for inserting bone pegs across the epiphyseal plate. The operation may also be used after slipping has occurred. The hip joint is exposed anteriorly by a Smith-Petersen incision, and the capsule is incised close to and parallel with the rectus tendon. This exposes the junction of the head and neck, and the pathological condition can easily be studied. Much more of this area can be seen if the hip is moved slowly in various directions.

Fig 6-A

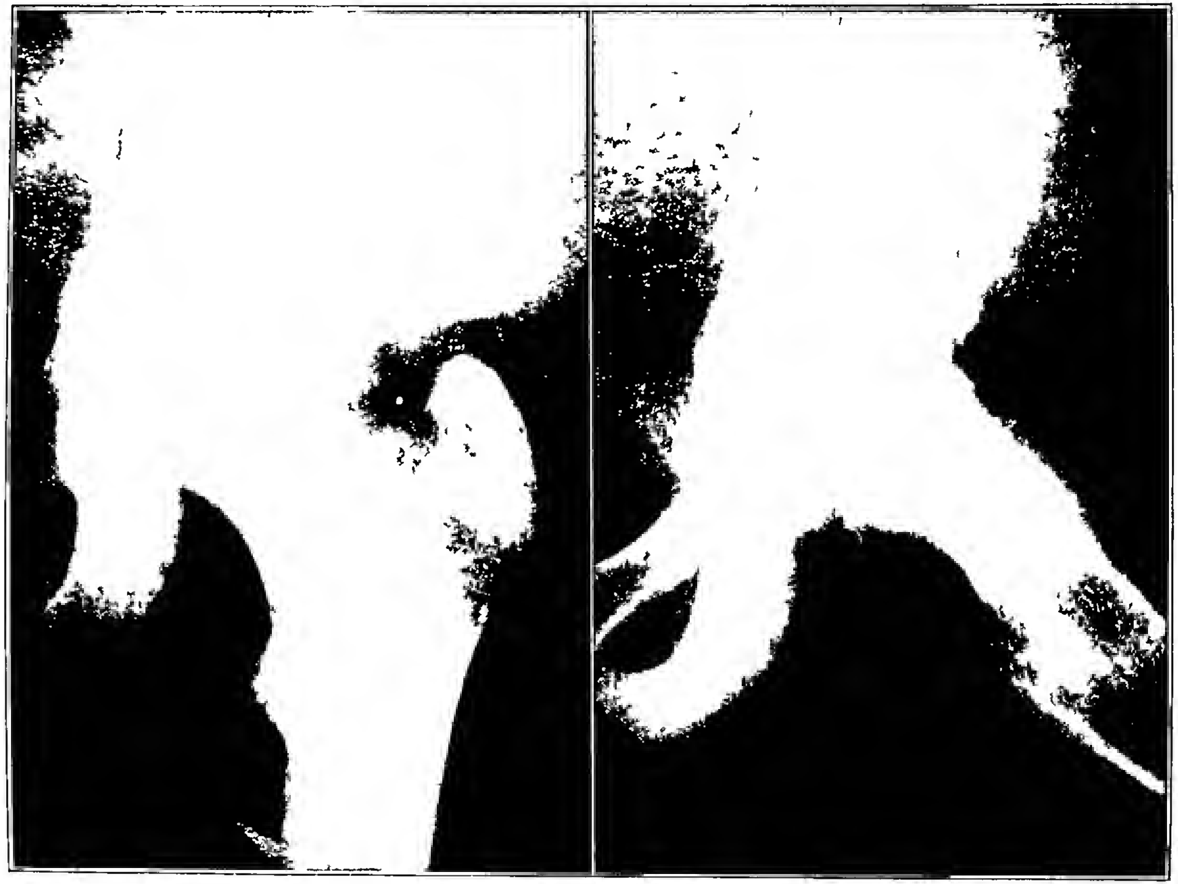

Fig 6-B

McC, a girl, aged fourteen years, had had pain and a limp for six months The pegging operation was done for slight slipping The clinical and roentgenographic result was excellent, with no degenerative changes,—the usual result from this operation

Fig 6-A September 11 1914 The epiphyseal line was slightly wide and irregular, with decalcification on the distal side The capsule was swollen Slight posterior displacement could be seen (lateral view)

The pegging operation was done on September 18

Fig 6-B November 11 Eight weeks after operation the epiphyseal line had healed and closed The pegs were being absorbed The head was healthy

Fig. 6-C

April 19, 1945. Seven months after operation, the epiphyseal line and pegs were nearly obliterated. The head and neck were healthy.

Three years after operation, there was no further displacement, there were no symptoms, and the index of motion was 100.

With an osteotome, a triangular fenestration is made in the neck anteriorly, close to its junction with the head. Through this opening, three holes are drilled with a Nicola gouge in tripedal fashion, through the epiphyseal plate into the head. If there is posterior slipping, it is easier to drill the holes. It is important that the position of the head be clearly visualized and that the holes be drilled in the proper directions and to the proper depths. In three hips the operation failed because the fenestration was not close to the head, and the holes and pegs did not reach the epiphyseal disc. Three pegs are cut from the anterior portion of the wing of the ilium, each about one and one-half inches long and three-sixteenths of an inch in diameter, and inserted into the drill holes. It is important that the pegs not be fractured in the process of removal, as a fractured peg is more likely to be absorbed; failure in one case apparently resulted from this cause. After the pegs have been inserted, the fenestration is covered with a small piece of muscle to prevent bleeding and to favor smooth healing. The wound is sutured anatomically, and a flannel or elastic-bandage spica is applied.

The extremity may be suspended and light traction may be used for a few days, or a plaster boot may be applied with a crossbar to hold the hip in slight internal rotation, especially if there is slipping and a tendency to external rotation. The position of the pegs is checked by roentgenograms. Active motion with support is begun a day or two after the operation, and, in two or three weeks, motion has usually returned to the preoperative range. Walking is begun eight to twelve weeks after operation, with crutches for the first week or two, when the roentgenograms reveal healing of the lesion and beginning union of the epiphysis. Full activity, including sports, may be resumed four months after operation. There is usually solid union of the epiphysis within six months after the operation, and complete closure of the epiphyseal line within a year. This premature union of the epiphysis rarely results in more than one-fourth inch of shortening at this age period, and the shortening is usually negligible. The range of motion in the hip is essentially normal if there has been no slip, and there is no disability for any activity, including athletics.

Fig 7-A

H , a girl, aged eleven years, had had symptoms for six months The pegging operation was done for moderate displacement A good clinical and roentgenographic result was obtained despite the displacement, there were no degenerative changes This is the usual result after this operation, and is far better than would have been obtained by open reduction or osteotomy of the neck

Fig 7-A March 20, 1946 The epiphyseal line was irregular, with a wide zone of irregular decalcification of the distal side There was posterior displacement of one-half inch, with mature callus in the inferior angle between the head and neck

On April 11 the pegging operation was done

Fig 7-B

September 10 Five months after operation, the epiphyseal line had healed and was closing, the pe[illegible] were being absorbed The head was healthy, the proximal end of the neck was recalcifying

FIG 7-C

In January 1949, almost three years after operation, the epiphyseal line and pegs were obliterated, the neck had recalcified, and the head and neck were healthy There was no further displacement

We have used the pegging operation on 134 hips, 120 cases were unilateral, and seven were bilateral The youngest patient, a girl, was eight years old, the oldest, a boy, was seventeen The operation was done in the preslipping stage on twenty-nine hips, after slipping had begun, on 102 The greatest amount of slipping was three-quarters of an inch The first of these operations was done in 1930, the last in this series, in December 1946 The follow-up period ranged from one to seventeen years, with an average of seven years Drilling alone, without pegs, was used in three of the hips The epiphysis slipped in one of these, nine months later, and an open reduction was done, healing of the other two was quite slow and was not influenced by the drilling

One failure resulted from absorption of the pegs, either because they were fractured in being removed from the ilium or because they were too small, the operation was repeated successfully Three other failures occurred because the pegs did not reach the epiphyseal plate, the operations were repeated, with success In no case did slipping occur after the pegging operation The lesion always healed within three months, and the epiphyseal plate began to close shortly afterward The clinical results have been excellent, with no pain, limp, or disability, even after strenuous athletics The range of motion has been essentially normal if no slipping occurred Internal rotation and sometimes flexion and abduction were proportionately limited if there was slipping The shortening due to closure of the epiphyseal plate was negligible There were no deaths and no deep wound infections No arthritic lipping developed in the hips in which little or no slipping took place

Nailing the Epiphysis

We have nailed the epiphysis with a Smith-Petersen nail, and have seen the results of nailing in several other series of cases The nailing operation is simpler than the pegging operation (particularly for the surgeon who is accustomed to using the nail for fracture of the neck of the femur), largely because the approach is simpler However, the danger of damage to the hip is greater, especially if the nail has to be driven in more than once, if it is driven too far, or if it does not remain wholly within the neck in its course to the head Degenerative changes in the head and even in the acetabulum have occurred in many of the hips in which nailing was done, whereas no such changes were seen after pegging Moreover, while a well-placed nail will prevent slipping of the epiphysis and will favor

eventual healing of the lesion and closure of the epiphyseal plate, the nail does not stimulate bone formation as do the pegs, and healing is slower Early weight-bearing is sometimes possible when the nail is used and, although the immediate result may be good, the eventual result is less satisfactory Wires may be used instead of the nail, with less likelihood of damage to the circulation at the hip or to the joint, but with a less stable fixation and no more rapid healing

Reduction by Manipulation

We have attempted closed reduction in twenty-eight cases by forceful abduction and internal rotation These hips were immobilized in plaster in abduction and internal rotation, and, while in this position, appeared to have at least partial reduction However, when the casts were removed and proper roentgenograms were taken, it was found that complete reduction had been obtained in only two cases, partial reduction in four, and none in the remainder Reduction failed because there was no way to hold the head and because of the resistance of the callus in the inferior angle There was little or no callus and little displacement of the hips with a partially successful reduction

The follow-up period ranged from one to ten years, averaging 4 5 years Moderate permanent limitation of motion was present in most of the hips, probably due to immobilization during the inflammatory period Degenerative changes of the head followed in several instances Manipulative reduction should be reserved for those hips with recent slipping and no callus If the displacement is corrected by closed manipulation, it is preferable to maintain the reduction with a nail rather than by immobilization in a plaster cast

Reduction by Strong Traction

Strong manual traction, estimated at 500 pounds, combined with internal rotation and abduction, was employed in 1932 in an attempt to effect reduction in seven cases of slipped epiphysis with callus in the inferior angle The downward displacement was corrected in most of these hips, but the posterior displacement usually was not corrected All were immobilized in plaster for ten or twelve weeks The eventual range of motion was poor in five cases, and good in only one Degenerative changes followed in all but one hip, probably due to circulatory damage at the time of reduction, as well as to immobilization in plaster under tension The results might have been better with nailing and active motion after reduction, rather than plaster

Traction-Reduction with Nail Fixation

Closed reduction by manual traction, with the extremity in flexion and internal rotation (Leadbetter manoeuvre), was done in five cases within a few days after the slipping The reduction was very good in three of the hips, and fair in two Fixation was accomplished with the Smith-Petersen nail, and early active motion with support was begun a few days after the operation Weight-bearing was started eight to ten weeks later The follow-up period varied from four to seven years, the result was good in each case, and a good range of motion was maintained The soft tissues evidently remain attached to the head in this type of reduction and the circulation is maintained, so that degenerative changes do not develop

Open Reduction

Open reduction of the displaced epiphysis was done in thirty-one hips, the first in 1920, with anatomical improvement in all cases and excellent anatomical reposition in nearly all It was necessary to separate the head from the neck in order to effect reduction and usually to remove callus from the inferior angle A nail was driven through the trochanter and neck into the head of one femur for internal fixation (1924) Twenty of the hips were immobilized in plaster for ten to twelve weeks Good clinical results were ob-

tained in only two of these; one patient was only eight years old at the time of operation. Two cases were complete failures; one patient later had an arthroplasty and one a hip fusion. Marked limitation of motion and degenerative changes were the rule.

Internal fixation, with active motion from the first week, was used with open reduction in eleven cases. Fixation was obtained with the ordinary nail in two cases, with the Smith-Petersen nail in eight, and with the Lippmann screw in two. The anatomical result was usually good. The range of motion was better in this group than in the group having immobilization, the index ranging from seven to ninety-six, with an average of sixty-six. The worst results occurred in the two hips in which the nail had been driven through the head into the acetabulum. Degenerative changes occurred in four of the hips, and arthritic lipping was common in those cases followed for several years.

Osteotomy of the Neck

The deformity was corrected by osteotomy through the femoral neck in three cases, the first in 1925, and the hips were immobilized in plaster for about twelve weeks. These cases were reported in 1931. Considerable anatomical correction was obtained, but limitation of motion and degenerative changes were usual. Probably the results would have been better with internal fixation and early motion. However, in two later cases having osteotomy of the neck with fixation by a Smith-Petersen nail, and early motion, the results have been only fair.

Subtrochanteric Osteotomy

The deformity was corrected indirectly in ten hips, at least to some extent, by subtrochanteric osteotomy. The lower fragment was abducted and internally rotated. The operation was usually done in the residual stage. The hip was immobilized in plaster in seven cases, once with a long nail to prevent flexion of the upper fragment. Two of these hips became quite stiff. Internal fixation with a blade-plate was used in two cases, with early motion, and Russell traction in one. The position of the hip was usually improved, but, in several cases treated by immobilization in plaster in extension, flexion of the upper fragment resulted in further deformity and shortening. Supracondylar osteotomy for correction of external-rotation deformity was used for one hip, with success. Subtrochanteric or supracondylar osteotomy is much less likely to result in damage to the circulation of the hip and degenerative changes than is closed or open reduction or osteotomy of the neck, but the position of the fragments cannot easily be controlled.

CONCLUSIONS

The hip should never be held in a position of tension, especially extension, abduction, and internal rotation, as this wrings out the blood vessels along the neck and still further embarrasses the circulation.

No operation should be done when acute pain and spasm are present, at least until after two or three weeks of bed rest. The treatment of choice is pegging of the epiphysis in the preslipping stage or before much slipping has occurred. The results of this operation have been excellent, and far better than with any of the other methods of treatment. Drilling without pegging has little or no effect on the course of the disease. Even the slipped epiphysis can be pegged, and the deformity can be corrected later by subtrochanteric osteotomy.

NOTE: For Discussion of this paper, see page 21 of this Volume of *The Journal* (January 1949).

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END RESULTS IN PHYSIOLOGICAL BLOCKING OF FLAIL JOINTS*

BY ALBERTO INCLÁN, M.D., HAVANA, CUBA

Many surgical procedures have been described to limit the motion of certain joints in a given direction, and are classified under the general heading of *arthroereisis*, in contrast to *arthrodesis*, in which all joint motion is abolished. The relative importance of this type of surgical technique may be gauged from the fact that it was one of the two principal subjects discussed at the Third International Congress of Orthopaedic Surgery, held at Bologna and Rome in 1936, under the inspiring presidency of the late Vittorio Putti.

The first arthroereisis or joint-blocking operation was performed by Wollenberg in 1912, for genu recurvatum. Toupet, in 1919, performed the first posterior block of the ankle. Since then many other surgeons have added new joint-blocking techniques to our surgical armamentarium, such as those of Putti, Campbell, Ombrédanne, Nové-Josserand, Camera, Salaverry, and others for the ankle joint, and those of Campbell and Mayer for the knee.

Other techniques, which utilize various intra-articular and para-articular soft structures and tendons in the manner of check ligaments, have been employed in an attempt to limit abnormal joint motion. It is our belief that, although these procedures may be successful in mild cases showing no alterations in joint configuration, they fall short of their goal in more severe cases, when growth and increasing weight throw a greater stress on joints and ligaments, resulting in a recurrence of abnormal motion.

Most techniques devised for joint-blocking depend upon the placing of bone grafts in such a way that they will mechanically impede the excursion of the joint in a certain direction. This type of operation has been accompanied by such a high incidence of functional failure due to absorption, fracture, or atrophy of the graft with a recurrence of abnormal motion, or to painful joint motion from secondary osteo-arthritis, that Branch, reviewing eighteen cases of posterior bone block of the ankle in 1939, stated: "The author hesitates to present a destructive paper such as this with no constructive criticism".

In an endeavor to secure a more physiological blocking of joints, altering the position of the joint surfaces themselves rather than blocking joint motion mechanically by means of grafts, the author has, since 1936, been employing the technique to be described. No originality is claimed, the principle is not new, and was embodied in techniques described by Putti in his second operation for anterior blocking of the ankle, by Bruce Gill in his operation for posterior ankle block, and by Lexer and Brett in their operation for genu recurvatum. This principle, however, has not been accorded proper emphasis by previous writers. It may be stated as consisting in the altering of the joint configuration in such a way that the range of motion is shortened without the introduction of a mechanical obstacle to normal excursion. This type of joint-blocking is termed "physiological", since the normal anatomical structures which make up the joint are not changed in substance, but are merely altered in their relation to one another. A perusal of the techniques to be described will clarify this concept.

Posterior Physiological Blocking of the Ankle

The operation is used in cases of paralytic drop-foot. A stabilizing triple arthrodesis of the talonavicular, talocalcaneal, and calcaneocuboid joints is first carried out, with resection of the head of the talus and correction of any varus or valgus deformities which may be present. While the next step is being performed, an assistant prepares the resected head of the talus, denuding one-half of the articular surface of cartilage and cutting a notch

* Read at the Joint Meeting of The American Orthopaedic Association, The British Orthopaedic Association, and The Canadian Orthopaedic Association, Quebec, Canada, June 4, 1948.

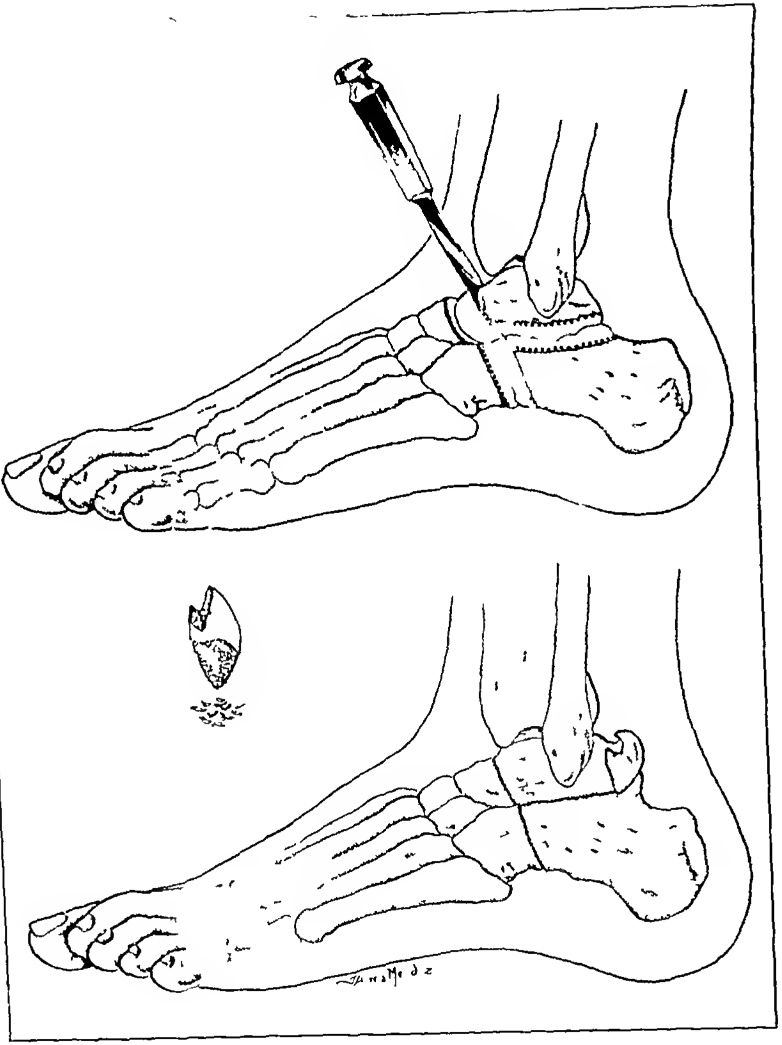

FIG 1

Fig 1 Physiological arthrocreisis for paralytic drop-foot, according to author's technique An osteochondral flap is raised from the posterior

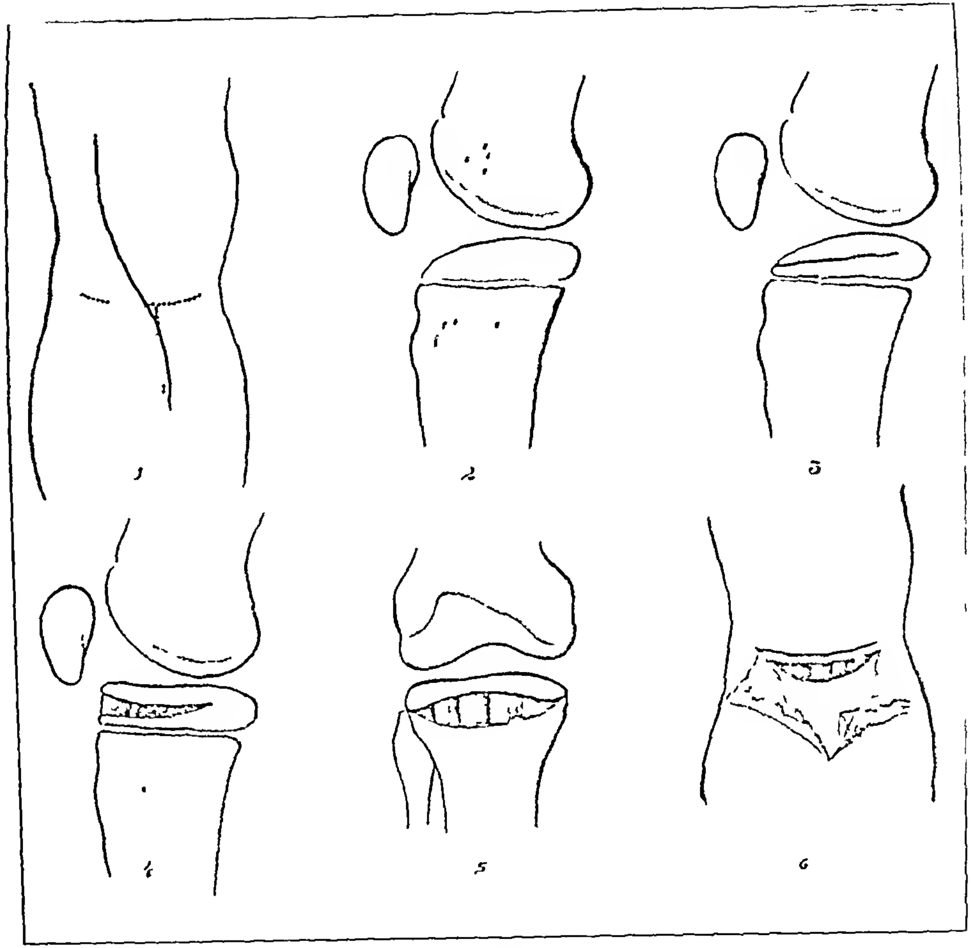

FIG 2

Fig 1 (*continued*) surface of the talus, and is maintained by the head of the talus, which is shaped like a cock's comb, thus modifying the articular surface so as to block plantar flexion (Reproduced, by permission, from *Cirugia Ortopedica y Traumatologia*)

Fig 2 Physiological arthroereisis of the knee joint to correct genu recurvatum Schematic illustration shows the different steps of the operation according to author's technique (Reproduced, by permission, from *Cirugia Ortopedica y Traumatologia*)

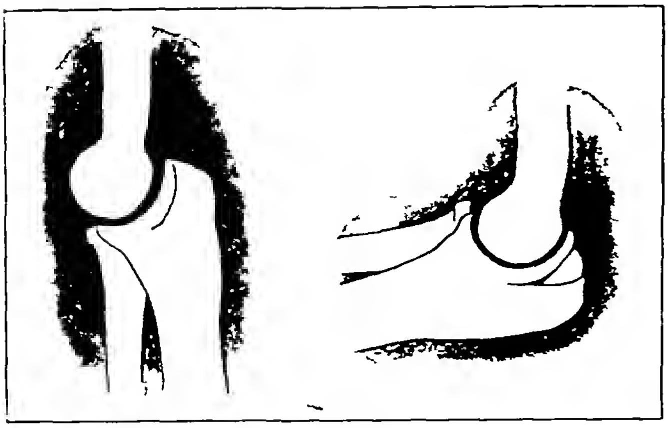

FIG 3

Schematic illustration of operative procedure for posterior blocking of the elbow

into the other half, so that the head of the talus assumes a shape reminiscent of a cock's comb (Fig 1) Following triple arthrodesis and closure of the operative wound, the patient is turned into the prone position, and a posterior longitudinal incision is made, parallel to the Achilles tendon The tendon is exposed and split by the Hoke Z-plastic technique, after which the underlying fat and ligamentous structures are split to expose the posterior surface of the talus and the superior surface of the calcaneus With the foot held in strong dorsiflexion, a curved osteotome is driven forward, just under the superior articular cartilage of the talus, and used as a lever to raise an osteocartilaginous flap While this flap is held in the raised position by the osteotome, a curved or angulated gouge is used to cut a deep vertical groove in the posterior surface of the talus and to raise a cortical flap from the superior surface of the calcaneus The previously prepared head of the talus is then placed in this bed, its denuded portion in contact with the raw surfaces of the talus and calcaneus, and its notch holding up the osteocartilaginous flap, which is lowered into it after the curved osteotome has been removed This elevation of the posterior portion of the superior articular surface of the talus effectively limits plantar flexion to about 10 degrees Although a portion of the head of the talus projects upward and posteriorly, it has no blocking action, and may be fractured or resorbed without in any way influencing the final results

Anterior Physiological Blocking of the Ankle

A corrective tarsal arthrodesis is first performed to correct the calcaneus or calcaneocavus deformity which may be present The anterior portion of the superior articular sur-

TABLE I

PHYSIOLOGICAL BLOCKING OF FLAIL JOINTS

Operation	No of Cases	Cases with Follow up (No)	(Per cent)
Posterior blocking of ankle	102	51	50
Anterior blocking of ankle	30	10	33
Anterior blocking of knee	8	6	75
Posterior blocking of elbow	1	1	100
Totals	141	68	

face of the talus is raised with an osteotome, and four wedges of bone, fashioned from the resected head of the talus, are placed under this osteocartilaginous flap to hold it up The outer portion of the flap must be raised much higher than the inner portion, if its blocking action is to be maintained when the foot is dorsiflexed while in the pronated or abducted position

Anterior Physiological Blocking of the Knee for Genu Recurvatum

A T-shaped incision is made, its horizontal portion just below the articular line of the knee joint, and its vertical limb along the anteromedial surface of the tibia The artic-

TABLE II

LENGTH OF FOLLOW-UP PERIOD IN SIXTY-EIGHT CASES

Time	No. of Cases
6 months to 1 year	3
1 to 5 years	37
6 to 10 years	18
11 years or more	10
Total	68

cartilage, with one-eighth of an inch of the underlying cancellous bone, is raised by an osteotome, driven from in front backward. A curved osteotome is used to develop this flap posteriorly, until the osteotomy almost reaches the posterior surface of the tibia. With the curved osteotome this osteocartilaginous flap is then bent upward, conforming to the curved surfaces of the femoral condyles (Fig. 2). Four wedges of bone, taken from the tibia

TABLE III

FINAL RESULTS AND LATE COMPLICATIONS IN FIFTY-ONE CASES OF POSTERIOR PHYSIOLOGICAL BLOCKING OF THE ANKLE

Classification	No. of Cases	Per cent	Plantar Flexion Possible (*Degrees*)	Complications *	No. of Cases	Per cent
Excellent	24	47	10 to 12	Foot deformity	8	16
Good	20	39	13 to 15	Absorption or fracture of head of talus	7	14
Fair	6	12	16 to 20	Absorption and partial loss of blocking	2	4
Poor	1	2	21 or more	Hypercorrection, resulting in slight calcaneus	1	2
				Pulmonary and hip tuberculosis	1	2

* No instances of ankylosis of the ankle, infection, arthritic changes, or arthritic pain were observed.

FIG. 4

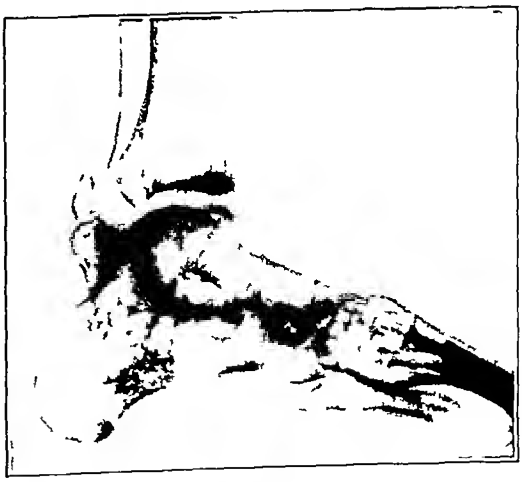

FIG. 5

Fig. 4. Roentgenographic aspect of paralytic drop-foot, ten years after operation. By modification of the articular surface of the talus, blocking mechanism has been set up. No arthritic changes are evident.

Fig. 5. Roentgenographic aspect of paralytic drop-foot, eight years after operation. That portion of the head of the talus shaped as a cock's comb has been fractured, the blocking effect is maintained by the modified articular surface of the posterior aspect of the talus.

TABLE IV

Final Results and Late Complications in Ten Cases of Anterior Physiological Blocking of the Ankle

Classification	No of Cases	Per cent	Dorsiflexion Possible (*Degrees*)	Complications *	No of Cases	Per cent
Excellent	5	50	10 to 12	Partial loss of blocking effect (4 to 10 degrees)	2	20
Good	2	20	13 to 15	Total loss of blocking effect	1	10
Fair	2	20	16 to 20	Revision of arthrodesis necessary	1	10
Poor	1	10	Over 20	Death from pulmonary tuberculosis, 2 years after operation	1	10

* No instances of infection, arthritic changes, pain on weight-bearing or walking, or ankylosis of th ankle were observed

and inserted into the osteotomy site, hold the flap in place This technique has been used successfully in the author's last six cases In the first two cases a parapatellar incision wa utilized, and the grafts were obtained from the patella We have found cortical graft from the tibia to be stronger and more suitable

Physiological Posterior Blocking of the Elbow

A posterolateral incision is begun two inches above the tip of the olecranon proce and is carried along the lateral border of the process to its base The tendon of the tricep is split in the mid-line, and the semilunar notch of the ulna is visualized An osteotomy i begun just posterior to the upper border of the articular cartilage, the osteotome bein driven downward, parallel to the cartilage The elbow is flexed to 90 degrees, and the flap is raised until it blocks further extension of the joint A wedge of bone, taken from th tibia, is inserted into the angle of the osteotomy to maintain the elevated position of th flap (Fig 3)

COMMENT

The author recommends the surgical procedures described for blocking joints because of the following reasons

1 The normal structure of the joint remains unaltered

2 Limitation of motion is obtained without disturbing the

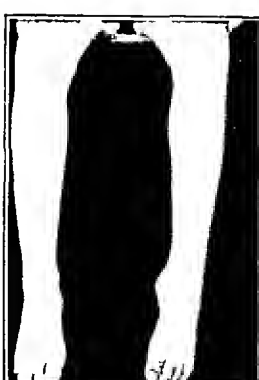

Fig 6-A

Fig 6-B

Fig 7-A

Fig 7-B

Fig 6-A J W Patient with paralytic drop-foot, before operation

Fig 6-B Demonstrating appearance and blocking effect after operation on the left foot by th author's technique

Figs 7-A and 7-B P S Photographs of a patient with extreme paralytic genu recurvatum, b and after operation

TABLE V

FINAL RESULTS AND LATE COMPLICATIONS IN SIX CASES OF ANTERIOR PHYSIOLOGICAL BLOCKING OF THE KNEE

Classification	No. of Cases	Per cent	Hyperextension Possible (Degrees)	Complications	No. of Cases	Per cent
Excellent	3	50	10 or less	Limitation of normal joint extension	1	16.6
Good	2	33	11 to 15	Infection	0	
Fair	0		16 to 20	Ankylosis of the knee	0	
Poor	1	17	Extension limited	Arthritic changes in the knee	0	

TABLE VI

FINAL RESULTS AND LATE COMPLICATIONS IN SIXTY-EIGHT CASES OF PHYSIOLOGICAL BLOCKING OF JOINTS

Classification	No. of Cases	Per cent	Complications *	No. of Cases	Per cent
Excellent	32	47.1	Postoperative deformity	10	14.7
Good	25	36.8	Partial loss of blocking	5	7.4
Fair	8	11.8	Overcorrection	2	2.9
Poor	3	4.4	Late pulmonary tuberculosis	1	1.5

* No instances of joint ankylosis, infection, arthritic changes, or arthritic pain were observed.

normal joint mechanism and its anatomy by the introduction of extraneous blocking elements.

3. The procedures may be carried out without damage to the joint itself.

4. The epiphyseal cartilages remain unharmed, future growth disturbances being thus avoided.

5. The blocking effect is more permanent than that obtained by other procedures, not based on the same principles.

STATISTICAL DATA

The end results of the first fifteen cases, in which anterior or posterior blocking of the ankle was carried out by the techniques already described, were presented by the author in 1938. A recent review of the statistics of the Poliomyelitis Service of the Mercedes Hospital has shown that, of the 781 operations carried out on the 1,123 patients registered, 141 were done by the author's techniques, to obtain physiological blocking of flail joints.

In ankle-blocking the end results in cases with an adequate follow-up were judged as follows:

Excellent. In this group solid triple arthrodesis of the tarsal joints was obtained, only 10 to 12 degrees of plantar flexion was possible, weight-bearing was normal, and there was no pain on walking or motion.

Good. These patients had plantar flexion of between 12 and 15 degrees, the heel was not prominent, but weight-bearing was otherwise normal, and no pain was present on motion or weight-bearing.

Fair. In these cases plantar flexion, varying between 15 and 20 degrees, was possible, a tendency to varus or valgus deformity was present, and there was no pain.

Poor. In this group the blocking effect was lost or plantar flexion was possible beyond 20 degrees. Complications included infection, osteo-arthritis of the ankle joint, deformity, ankylosis of the ankle, and pain on motion or weight-bearing.

Of the total number of joint-blocking operations performed in all joints by these techniques, the end results were good or excellent in 85 per cent of the cases, in 4 4 per cent they were poor Only sixty-eight cases in which an adequate follow-up was possible are included in this total Of these, twenty-eight patients had been operated upon from five to ten or more years ago The statistical data are given in greater detail in Tables I to VI inclusive

CONCLUSIONS

End results, obtained after twelve years of experience with techniques devised for securing physiological blocking of flail joints, are presented The author's aim is to demonstrate the advantages of these and similar techniques, which are based on physiological restriction of a specific joint motion by alteration of the anatomical position or configuration of the joint surface

The physiological blocking operations performed at the ankle and knee have shown permanent satisfactory results, classified as either good or excellent, in 85 per cent of cases for as long as twelve years following operation

Postoperative infections, ankylosis, or arthritis did not occur in any of the cases in this series

Late loss, either partial or complete, of the original blocking occurred in 7 4 per cent of the cases reviewed

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FRACTURES OF BOTH BONES OF THE FOREARM IN ADULTS *

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From the Campbell Clinic and the University of Tennessee, Memphis

Fractures of the shafts of both bones of the forearm present specific problems, in addition to those difficulties which are common to all fractures of shafts of the long bones. Besides the necessity for regaining length, apposition, and axial alignment, normal rotational alignment must be regained, if a good range of pronation and supination is to be recovered. The chances for the occurrence of malunion and non-union are greater, because of the difficulties in reducing and maintaining the reduction of two parallel bones in the presence of the pronating and supinating muscles, which have angulatory as well as rotatory influences. Because of these factors, the end results obtained in the treatment of these fractures have frequently left much to be desired, especially in adults where the compensatory growth changes of childhood are lacking, and where the ability to recover with an excellent functional result, in the face of only a fair anatomical result, is usually absent. The purpose of this study was to determine the results obtained in the treatment of these fractures in adults, to determine the causes of failure, and to make recommendations for the exact treatment of these fractures.

One hundred cases of fresh fractures of the shafts of both bones of the forearm in adults (over fifteen years of age) treated by the Staff of the Campbell Clinic were studied. Colles's fractures and fractures of the head of the radius and of the olecranon were excluded from the study. The cases were grouped into the following categories, according to the method of treatment employed:

Manipulation		41
Open reduction		
Without rigid internal fixation	13	
With plates	20	
With primary bone grafts	15	
With intramedullary wires	11	59
	——	——
Total cases		100

Because of the variation in types and levels of fractures, the frequent occurrence of soft-tissue injury, and the presence of fractures elsewhere in the extremity or the body, it has been impossible to arbitrarily set up criteria based upon such factors as limitation of motion, loss of strength, and pain, by which to evaluate the end results in each case. Thus, in some cases with extensive soft-tissue injury in addition to the fractures, when making the final evaluation, limitation of motion as the result of scarring or loss of muscle or nerve function must be taken into consideration.

In grouping the end results, the excellent and good results have been accepted as satisfactory, while the fair and poor results have been considered unsatisfactory.

Early in the study, it became apparent that rotational alignment had been given considerably less attention than axial alignment and end-to-end engagement, both at the time of initial reduction and in the evaluation of the end results. Rotational alignment of the radius following fractures of the forearm has been briefly mentioned in the literature, but it was not until 1945 that Evans offered an accurate method of determining the rotational alignment by roentgenograms. Evans strongly re-emphasized the fact that any degree of error in rotational reduction would be followed by a corresponding limitation of pronation and supination of the forearm. In the past, it has been advised that fractures

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 27, 1949.

of the proximal thirds of both bones of the forearm should be immobilized in supination, those of the middle third in mid-position, and those of the lower third in either pronation or mid-position. These positions were chosen because of the anatomical arrangement and balance of muscle pull of the pronators and supinators of the forearm at the various levels. All cases in this series were studied in accord with Evans's suggestion, the degree of residual rotational deformity of the proximal radial fragment being determined. In a high percentage of cases, limitation of forearm rotation was found to correspond closely to the residual bony rotational deformity. As the study progressed, it was found that the end results regarding pronation and supination could be predicted with a surprising degree of accuracy from a study of the roentgenograms alone.

Determination of the degree of rotation of the proximal radial fragment is based upon the distinctive configuration of the proximal portion of the radius, particularly that of the bicipital tuberosity, the relationship of its cancellous portion to the shaft of the radius, and the shape of the bicipital curve of the radius. A calibration chart of the normal must be made with the forearm in varying degrees of pronation and supination, to determine the rotational position of the proximal radial fragment.

Evans has suggested that the "tuberosity-view" roentgenograms be made with the following constant technique. An anteroposterior view of the elbow joint is taken with the tube tilted 20 degrees toward the olecranon. The tip of the olecranon is placed one-third of the way along the plate, with the elbow flexed to 90 degrees, care being taken that both condyles of the humerus are at the same level. In attempting a manipulative reduction of the fracture, a comparative "tuberosity view" of the opposite elbow should be made, if there is any question as to the rotational position of the proximal radial fragment. Reduction of the fracture is then performed with the forearm in the position of rotation which corresponds to that of the proximal radial fragment, since the rotation of this fragment cannot be controlled, and the distal fragment must be brought into alignment with it; after the reduction, the forearm is immobilized in that position. If an open reduction is to be performed, in a case in which the radial fracture is comminuted, arrangements should be made for x-rays to be taken with a portable machine during the operation, should any question of rotational alignment arise.

ANALYSIS OF RESULTS

The end results have been unsatisfactory in a relatively high percentage of cases of fractures of both bones of the forearm in adults. In general, unless gross limitation of motion, gross deformity, or pain were present, the patients had little or no complaint. Limitations of extremes of pronation and supination were usually accepted by the patient, since abduction and internal rotation at the shoulder adequately supplemented mild limitation of pronation, and adduction and external rotation of the shoulder supplemented, to a lesser extent, limitation of supination. (One patient, a typist, complained specifically of inability to pronate the forearm sufficiently to place the fingers on the keyboard.) Pain was not present unless union was incomplete, or unless there was excessive bone proliferation which resulted in a painful bone block to rotation.

Pronation was rarely limited to an appreciable degree, unless anterior angulation of the radius resulted in a bone block; supination, however, was limited very frequently, due to the following causes, listed in order of frequency: (1) residual supination of the proximal radial fragment, due to incomplete reduction, (2) narrowing of the interosseous space, due to appositional angulation of one or both bones, (3) residual posterior angulation of the ulnar fracture, forming a bone block, and (4) derangement of the inferior radio-ulnar joint.

Inferior radio-ulnar instability was found infrequently, despite the rather common finding of inferior radio-ulnar axial subluxation due to slight radial shortening. Clinical symptoms of pain and instability were ordinarily found only in the presence of appo-

tional angulation of the radius or ulna, or of an associated fracture of the ulnar styloid process with non-union. In other words, a piston-like or axial subluxation of the inferior radio-ulnar joint was usually asymptomatic, but symptoms were present if there was anterior or posterior angulation of one of the two bones.

MANIPULATION

The results following manipulation were, in general, unsatisfactory. Of forty-one cases studied, there were three excellent, nine good, seventeen fair, and twelve poor results (or 29 per cent. satisfactory results and 71 per cent. unsatisfactory results). There were five cases of non-union, an incidence of 12 per cent.; in two of these, both bones were involved and in three the ulna alone was involved. Solid union required a longer period of time than is generally thought necessary, averaging four and one-half to five months. Narrowing of the interosseous space, angular deformity, and rotational deformity were present in a majority of the cases. It is obvious that better results would have followed open reduction and some form of internal fixation. In 60 per cent. of the cases, residual rotational deformity of from 25 to 60 degrees was present, the proximal radial fragment being supinated, with resulting proportional limitation of supination. This is true for fractures of the lower third, as well as for those of the middle third and upper third. In the lower third, the pull of the pronator quadratus resulted in appositional

FIG. 1-A
August 27, 1940

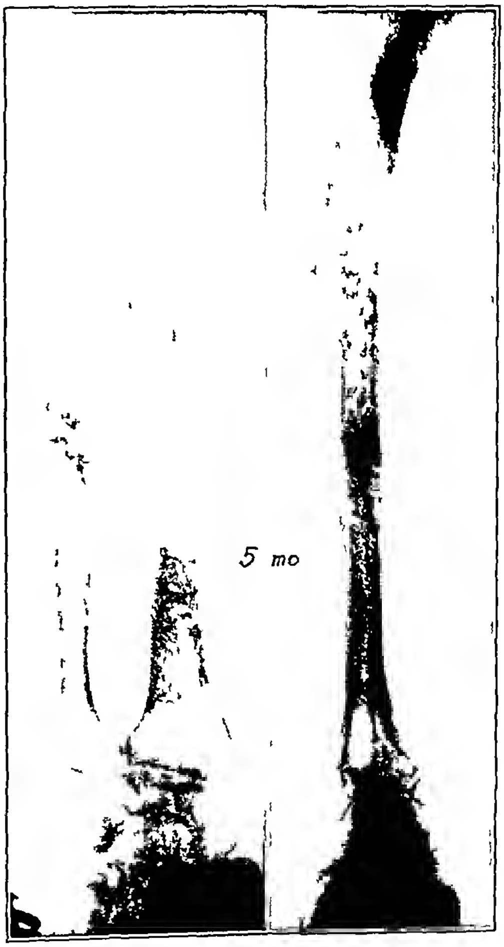


FIG. 1-B
January 31, 1941

Oblique fractures of the middle thirds of both bones of the forearm are shown. Manipulative reduction was unsatisfactory, because of failure to obtain engagement of the radial fracture or to correct rotational deformity of the radius of 90 degrees. There was subsequent loss of interosseous space; supination was absent. Primary open reduction of both fractures should have been done, with application of plates or onlay grafts.

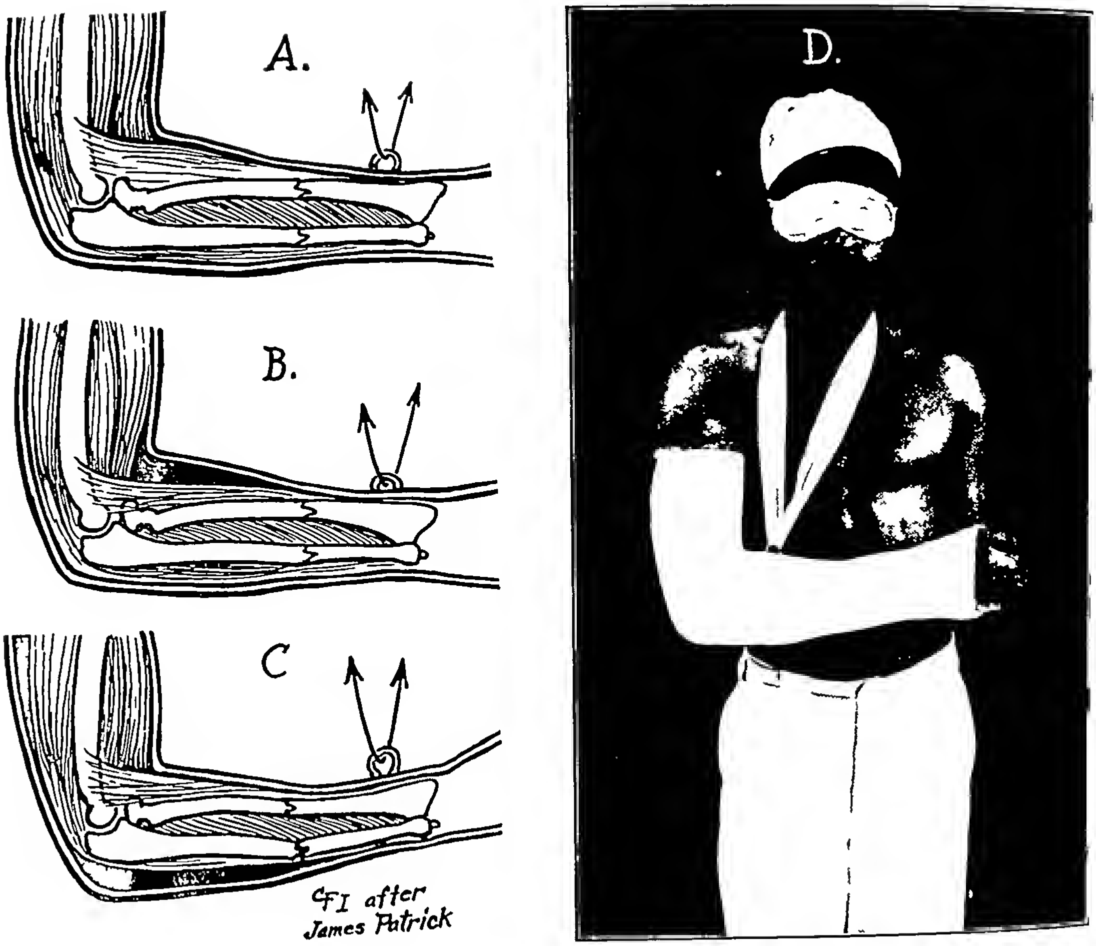


Fig 2

Angulation of radius and ulna during period of cast immobilization is illustrated *A* Immediately after reduction, cast fits snugly *B* Atrophy of forearm muscles has taken place, with consequent loosening of cast in upper half of forearm *C* Cast has sagged while still holding distal fragments firmly, thus angulating radius and ulna *D* Method of suspending cast by sling, as advised by Patrick

angulation, narrowing of the interosseous space, and a resultant loss of supination, in addition, the proximal radial fragment was usually in some degree of supination

Fractures of the middle third also gave unsatisfactory results in most instances It is even more difficult to obtain and maintain a satisfactory reduction in these and the fractures in the upper third and, if there is comminution or obliquity of one or both bones open reduction is usually necessary (Figs 1-A and 1-B) The rotational alignment must be checked, involving the making of comparative tuberosity-angle views of the opposite normal elbow, if necessary, so that the forearm may be reduced in the proper rotational alignment If the fractures are transverse, an attempt at manipulative reduction appears justified, but, unless a stable anatomical reduction can be obtained, open reduction and internal fixation should be resorted to without delay

No accurate correlation of rotational deformity to the level of fractures could be made, but it appears, from the results of this study, that, in most fractures of both bones of the forearm in adults, the arm should be immobilized in a position of supination following manipulative reduction

Patrick pointed out that one of the causes for angulation of the radius during immobilization in plaster is that the weight of the cast is largely supported by a sling at the wrist (Fig 2,*A*) The muscle bellies of the forearm are located chiefly in its upper half while in the lower half the bones are largely surrounded by tendons Consequently, as the muscles in the proximal half of the forearm become atrophied, the cast becomes loose and sags, while the distal halves of both bones remain relatively firmly immobilized, and consequently angulation may occur (Figs 2,*B* and 2,*C*) Patrick advised that a sling be

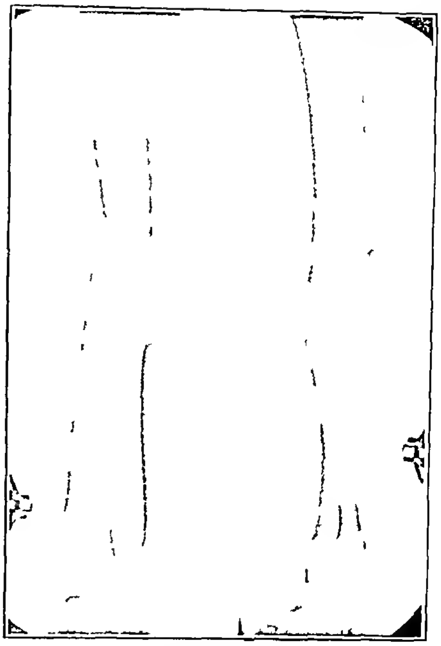


Fig. 3-A
May 5, 1932

Fig. 3-B
October 4, 1932

Unsatisfactory result following open reduction of comminuted fractures in the middle third is shown. No internal fixation was applied to ulna; wire loop was applied to radius. Note residual rotational deformity of radius, approaching 90 degrees of supination.

corporated in the plaster just below the elbow, for suspension (Fig. 2,*D*). The authors have had no personal experience with this method, but Patrick has had no difficulty with the development of angulation of the radius since he adopted this method of cast suspension.

OPEN REDUCTION

Open Reduction without Rigid Internal Fixation

In earlier years, simple open reduction without internal fixation was employed, if the fractures were stable after reduction. If there was comminution or obliquity of either fracture, internal fixation, such as a figure-of-eight wire or a catgut suture, was placed across the fracture site. Thirteen cases in this series were treated by this method, with two good, six fair, and five poor results. In other words, approximately 85 per cent of these were unsatisfactory. Angulation and displacement with associated cosmetic and functional disturbances of varying degrees were the cause of unsatisfactory results in most instances. Residual rotational deformity was present in several cases, despite the fact that the fractures were reduced under direct vision, emphasizing the fact that rotational alignment has not always been restored at the time of open reduction (Figs. 3-A and 3-B). In this group of thirteen cases, there were two instances of delayed union, and non-union of one or both bones occurred in six of the thirteen cases. This method of treatment would thus appear to be inadequate and unsatisfactory. If open reduction is performed, rigid internal fixation of both bones should be employed, even though the fragments can be firmly locked together by good serrations. End-to-end engagement alone will not guarantee maintenance of alignment.

Open Reduction and Plate Fixation

This method was employed in twenty instances with the following results: six excellent, one good, five fair, and eight poor (or 35 per cent satisfactory results and 65 per cent unsatisfactory results). In this group of twenty cases were two instances of delayed union of the ulna, one of delayed union of the ulna with non-union of the radius, and three of non-union of the ulna alone. These complications were the result of the use of plates or

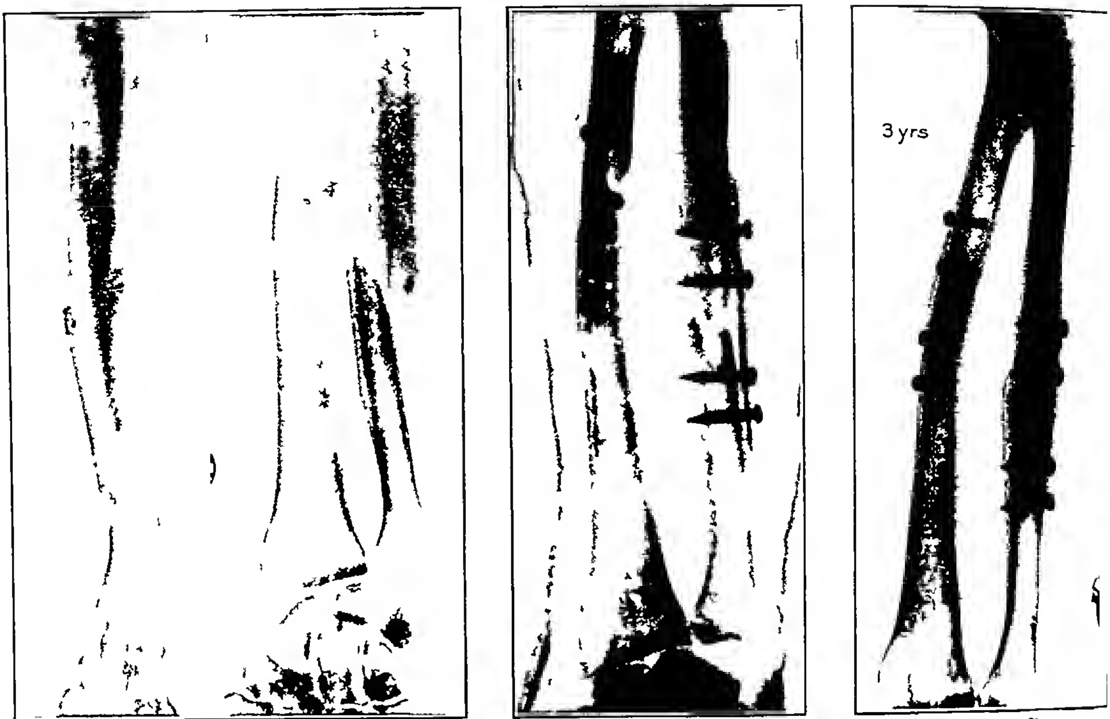


Fig 4-A
May 18, 1945

Fig 4-B
June 8, 1945

Fig 4-C
September 28, 1948

Primary onlay grafts to both bones, with excellent end result Note screws used to transfix comminuted radial fragment Consolidation was complete in twelve weeks

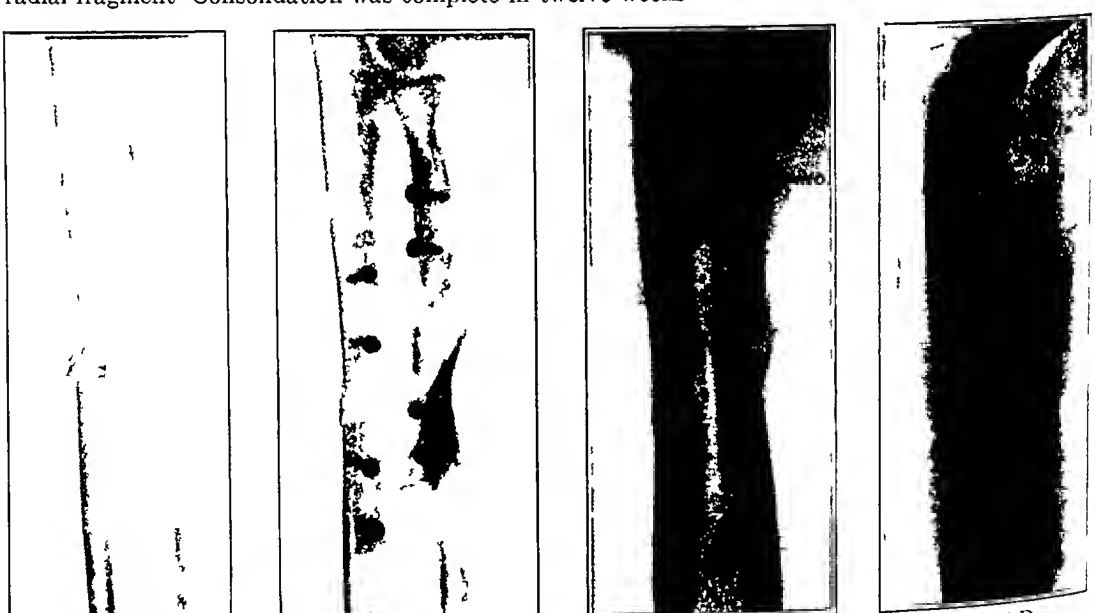


Fig 5-A
August 21, 1943

Fig 5-B
September 7, 1943

Fig 5-C
October 14, 1943

Fig 5-D
January 4, 1944

Comminuted fractures of both bones Primary onlay grafts have been applied, with accessory cancellous bone Note failure to correct rotational deformity of radius of 80 degrees, and uncorrected narrowing of interosseous space Accessory cancellous bone is a major factor in the production of synostosis

screws of inadequate length, absorption at the fracture site, or failure of union of a comminuted fracture The excellent results followed open reduction and plating of simple oblique or transverse fractures In three of the twenty cases, residual rotational deformity of the radius occurred, despite reduction of the fracture under direct vision

Open Reduction with Primary Onlay Grafts

Since 1942, in an effort to treat fractures of the shafts of both bones of the forearm in adults in a more definitive manner, primary onlay bone grafts have been used in selected cases In the same year, Kellogg Speed reported its use

Primary grafting has been employed in fifteen cases with six excellent results, three good results, one fair result, and five poor results. In all instances of fractures in the middle third, where onlay grafts were applied to both bones, satisfactory results were obtained (Figs. 4-A through 4-C). In two instances, a graft was applied to the ulna and a single screw was inserted across an oblique radial fracture; in both cases, the ulnar fracture healed satisfactorily, but the radial fracture angulated toward the ulna with resultant narrowing of the interosseous space and malunion. In three cases, where there was comminution of both bones in the proximal third, onlay grafts were applied and cancellous bone was placed about the fracture sites. In two of the three cases, both grafts fractured with resulting angulation and synostosis; in the third case, the grafts were applied with the radius in poor alignment and with narrowing of the interosseous space. Here, too, synostosis ensued (Figs. 5-A through 5-D). It is evident, first, that, if primary grafts are employed they should be applied to both bones, and, second, that cancellous bone packed about the fracture site, particularly in fractures of the proximal third of the forearm, may lead to a synostosis. It is now advised that a "bone plate" of cortical bone be employed, the graft being at least six times the diameter of the shaft in length and two-thirds its diameter in width. It should be beveled at each end and fixed with four or more screws. Any large comminuted fragment should be fixed with an additional screw to either the proximal or the distal fragment.

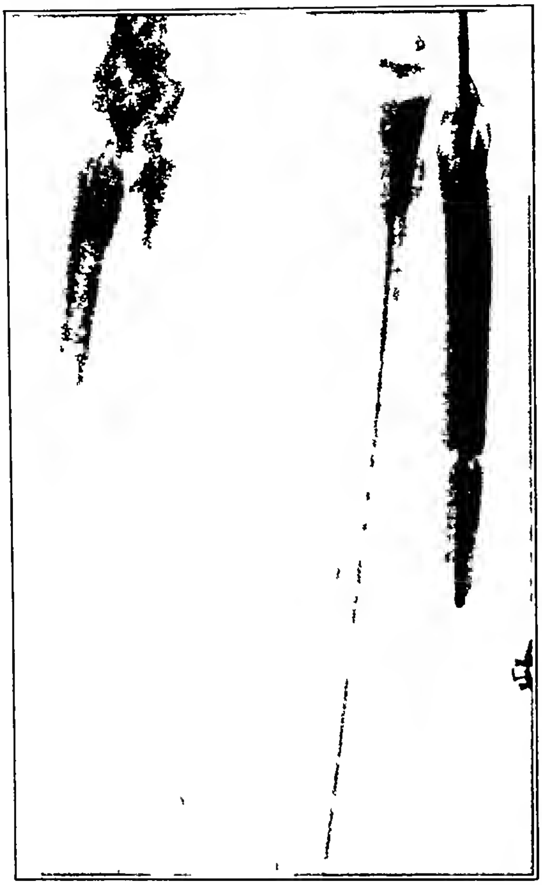
In this series, homogenous bank bone has been employed in four instances; although the series is too small to permit any conclusions as to its value as compared with autogenous bone, the results have been as satisfactory. The use of bank bone makes a primary graft of both bones as simple a procedure and of no greater magnitude than the plating of both bones.

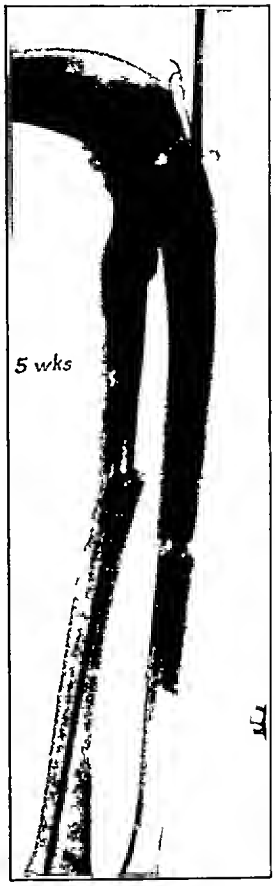
Fig. 6-A
February 21, 1947

Fig. 6-B
July 3, 1947

Fig. 6-C
November 27, 1948

Compound fractures of both bones with severe soft-tissue injury. Intramedullary fixation has not maintained anatomical position of radius, but has maintained good general position and alignment for secondary reconstructive procedures. The screws which are still present in the radius caused no symptoms and, at the patient's request, were not removed.





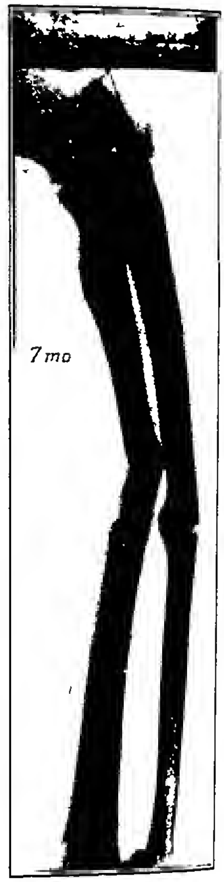


Fig. 7-A
August 24, 1947

Fig. 7-B
October 4, 1947

Fig. 7-C
March 19, 1948

Severe bone and soft-tissue injury. Ulnar wire should have been introduced farther down medullary canal and should not have been allowed to protrude through skin over olecranon. Wire was removed before consolidation was complete. Subsequent angulation of radius is not prevented by intramedullary Kirschner wire.

In the cases in which primary onlay bone grafts were employed, union was complete in an average of ten to twelve weeks. Thus, it would appear that consolidation takes place more rapidly following primary grafting than with the use of other methods.

Open Reduction and Intramedullary Fixation

Intramedullary wire fixation was used in eleven cases in this series; actually, it has been employed in a total of approximately thirty-five cases of forearm fractures, but the other cases were unsuitable for study because of inadequate follow-up. This form of treatment was used in those cases in which the forearms were severely traumatized and the fractures were comminuted, often presenting double fractures of either the radius or ulna (Figs. 6-A through 6-C). This form of fixation was used in these cases of segmental fracture because plating or grafting, even though otherwise feasible, would have required sufficient soft-tissue stripping to endanger the viability of the intermediate fragment. There were two excellent, three good, three fair, and three poor results in this group. The average time required for union was four and one-half to five months, comparable to the length of time required for union of fractures treated by manipulation. The causes of unsatisfactory results were: (1) failure to maintain correct rotational alignment of the radius, (2) angulation in cases where a single Kirschner wire was used in a double fracture of the radius, (3) angulation at the fracture sites, due to too early removal of internal and external fixation, and (4) non-union (Figs. 7-A through 7-C).

Although no definite evaluation of intramedullary fixation in forearm fractures can be made from these cases alone, our experience with the method has brought out several valuable points. The fixation afforded by an intramedullary wire or nail in ulnar fracture

is much more satisfactory than that in the radius, since its medullary canal is relatively straight and the wire or Küntscher nail can easily be inserted through the olecranon. The intramedullary wire or nail is inserted in the radius with difficulty, however, since it must be inserted through the radial styloid process or through a large drill hole on the dorsum of the radius in the vicinity of Lister's tubercle. The wire or nail must then pass into the medullary cavity obliquely, and, if it does not follow the normal curve of the bone, the radius will be straightened to some extent, with consequent narrowing of the interosseous space. The Kirschner wire has proved to be easy to insert, but does not have sufficient stability to prevent rotation or appositional angulation of the radius. This has been found particularly true in double or sectional fractures of the radius. In fractures of the lower third of the radius, the use of the Kuntscher nail is practical, since the nail does not have to be introduced the entire length of the radius. However, in certain segmental fractures of the radius, it is safer to use intramedullary Kirschner wires, even though they do not perfectly maintain the fracture, than to strip the shaft of the radius the required extent for grafting or plating, with consequent risk of devitalizing a short segmental fragment. It is possible that the employment of two or more Kirschner wires, as utilized by Lambrinudi, may prove more satisfactory for maintaining radial fractures than a single wire.

Severe compound fractures can be fixed with intramedullary wires without markedly increasing the danger of dissemination of infection along the medullary canal or massive sequestration, if the fundamental surgical principles of thorough irrigation and débridement, followed by adequate chemotherapeutic and antibiotic therapy, are observed. Even in those cases in which non-union resulted, this method has had the advantage of maintaining length and alignment, greatly simplifying secondary reconstructive procedures.

Both internal and external fixation must be maintained until all fractures are shown roentgenographically to be consolidated, for clinical determination of consolidation is obviously unreliable. Despite the presence of intramedullary fixation, resumption of function before bony consolidation is complete may cause delayed union with excess callus formation or even non-union.

RECOMMENDATIONS

As a general rule, it is advocated that oblique or comminuted fractures of both bones of the forearm be treated by open reduction and internal fixation. Transverse fractures may be manipulated, but, if a stable reduction with anatomical alignment of all fragments cannot be obtained, one should then proceed to open reduction without delay. In fractures of the upper third, it is difficult to obtain anatomical alignment except by open reduction. When open reduction has been delayed, it is difficult to reduce the fractures, particularly as far as rotational alignment is concerned. If the fracture is reasonably fresh, the serrations of the bone ends can easily be fitted into their proper niches, to ensure correct rotational alignment. If there is comminution, a primary graft of proper size should be applied. In fractures of the lower third, it is recommended that some form of internal fixation be employed. An intramedullary ulnar wire introduced through the olecranon, and a Kuntscher nail inserted into the radius from its distal portion, will maintain position and alignment adequately.

The approach employed in open reduction of the ulna presents no problem, since the bone is subcutaneous throughout its length. In the upper and middle thirds, the plate or graft should be applied to the dorsal surface of the bone, in order not to block pronation, while, in the lower third, the plate or graft should be placed on the volar surface, beneath the flexor muscles, rather than on a superficial surface. The approach to the radial shaft, however, is less simple. In the upper third, where the supinator must be elevated, the anterior approach of Henry permits easy elevation of the supinator muscle from its insertion, without endangering the deep branch of the radial nerve. In the middle third, the posterior approach of Thompson is suitable, or, if preferred, Henry's anterior approach

may be made There is little danger of injuring a part of the radial nerve below the upper third, since the nerve is sensory in character distal to this point In the lower third, the distal portion of Henry's approach, as advised by King, should be employed An anterolateral incision is made over the lower third of the forearm, which permits application of the plate or graft on the flat flexor surface of the radius beneath the flexor muscles

The screws should not protrude beyond the opposite cortex, the use of screws which are too long may cause irritation and limitation of supination or pronation

When open reduction is done, a tourniquet should be used, before the incisions are closed, the tourniquet should be removed and hemostasis secured This is advisable regardless of the site of fracture, but it is imperative, if the anterior approach of Henry to the upper third of the radius has been employed In one case in this series, Volkmann's contracture resulted from failure to ligate the recurrent branch of the radial artery In closing the wound, the deep fascia should be snugly sutured, in order to prevent depression of the operative scar In all cases of fractures of the shafts of both bones of the forearm, a snug plaster-of-Paris cast, extending from the axilla to the distal palmar crease, with the elbow flexed to 90 degrees, should be employed until all fractures are shown to be consolidated, both clinically and roentgenographically

CONCLUSIONS

1 An end-result study of 100 cases of fresh fractures of the shafts of both bones of the forearm in adults has revealed a high incidence of unsatisfactory results

2 Improper rotational alignment is an important causative factor in a high percentage of poor results

3 Transverse fractures in the middle and lower thirds of both bones of the forearm may in some instances, be satisfactorily reduced by closed manipulation, if reduction is performed with correct rotational alignment

4 Fractures of the upper third of the forearm, and oblique or comminuted fractures at any level in the forearm, are best treated by open reduction and rigid internal fixation of both bones

5 Simple transverse and oblique fractures of the shafts may be plated, but comminuted fractures of the shafts are most satisfactorily treated by primary bone-grafting

6 Intramedullary fixation is a very satisfactory method of maintaining the reduction and alignment of complicated fractures of the shafts of both bones of the forearm, particularly where there is major soft-tissue injury and where other methods of internal fixation, such as plating and primary grafting, are contra-indicated

7 External plaster fixation must be maintained until union is clinically and roentgenographically complete, regardless of the type of internal fixation employed

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THE EXPERIMENTAL PRODUCTION OF ECTOPIC CARTILAGE AND BONE IN THE MUSCLES OF RABBITS *

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A specific osteogenetic substance has been hypothesized by several investigators in the last decade. Levander obtained cartilage or bone, or both, in 23 per cent. of seventy rabbits by injection of alcoholic extracts of autologous bone or fracture callus into the rectus femoris muscle. Injections into sixty animals of alcohol alone and into twenty animals of alcoholic extracts of connective tissue, striated, or smooth muscle, all yielded negative results.

Annersten demonstrated chondrogenesis or osteogenesis in half of the rabbits injected with concentrated homologous extracts and in one-fourth of those injected with heterologous extracts (calves' bones). On the basis of one positive result of ten tests with homologous extract of kidney, and one positive result of six tests with dialyzed urine of rabbits, Annersten supported the hypothesis of Levander that an osteogenetic substance circulates in the blood and is excreted by the kidneys. He obtained four positive results among a large series of controls.

Bertelsen compared alcoholic extracts of whole bone with those of marrow, cortex, epiphysis, and periosteum. In a total of sixty muscles in thirty-three rabbits, he obtained twenty-nine positive results (48 per cent.). Extracts of bone marrow were distinctly superior (83 per cent. positive) to the other fractions. Among forty-one control experiments with extracts of several tissues, one positive result was obtained with extract of liver.

Lacroix[11,12] obtained cartilage, bone, and hematopoietic marrow forty-one days after the injection of alcoholic extracts of epiphyses of newborn rabbits into the thigh muscles of other rabbits. He emphasized that his extracts of epiphyses that were largely cartilaginous produced chondro-osseous tissue which resembled more closely a bone than that obtained by other workers who had extracted bone or cartilage of older animals. He suggested that the hypothetical substance be called "osteogenin" and was challenged by Levander and Willstaedt, who claimed that prior discovery had been reported.

Rendano obtained cartilage in one of twenty-two rabbits with extracts of bone; six controls injected with 40 per cent. alcohol were negative.

Martin Lagos and Zarapico Romero obtained cartilage and bone, either alone or in combination, in seven of eighty-seven rabbits (8 per cent.) following injection of 40 per cent. alcohol into the rectus femoris. They concluded that the action of an osseous extract was not necessary for obtaining positive results.

Blum reported that injection of a mixture of phosphatase, glycerophosphate, and alginate gel into the rectus femoris of rabbits led to the formation of ectopic bone after thirty-five days, whereas no bone was obtained with the alginate gel alone.

The initial purpose of the present investigation was the substantiation of the results of Levander and of Annersten. When it became evident early in the course of the work that positive results could be obtained in an appreciable number of animals following injection of alcohol alone, the aim was redirected from a study of extracts to a study of the factors modifying the results with alcohol alone. Some animals were injected with calcium chloride, since the alginate gel-phosphatase mixtures of Blum contained this irritant. The investigative routine adopted and the results obtained are presented here.

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TABLE I

EXP NO	INITIAL DATE	RABBIT NOS	SEX M,F	AV AGE MOS	SUBSTANCE INJECTED	TRICEPS NO MUSC*	TRICEPS NO POS	QUADRICEPS NO MUSC	QUADRICEPS NO POS
3	9-8-46	24-37	5,9	3-4	EXTR MUSC	6	5	4	0
					EXTR BONE	5	2	7	2
4	11-15-46	38-43	3,3	3-5	40% ALC-HCL	6	6	6	0
5	2-28-46	44-49	3,3	5^+	40% ALC	6	2	5	0
					EXTR BONE	6	2	6	1
6	2-6-47	50-53	3,1	2^-	40% ALC	3	2	3	1
					BLOOD	0	0	0	0
7	2-22-47	54-62	5,4	3-4	40% ALC	7	4	8	2
					2% $CACL_2$	8	1	8	2
8	2-28-47	63-70	4,4	3	40% ALC	7	3	8	2
					2% $CACL_2$	6	0	8	1
9	4-2-47	71-81	8,3	1-1 1/4	40% ALC	8	6	10	7
					1% $CACL_2$	10	1	10	2
10	4-3-47	82-84	1,2	1-1 1/4	1% $CACL_2$	3	0	3	2
					1% NH_4CL	0	0	0	0

*CONTAINING MACROSCOPIC LESIONS NOT GROSSLY INFECTED

Pos = positive Extr = extract

PROCEDURE

A summary of the experiments is given in Table I Experiments 1 and 2, which are considered preliminary, are not included The rabbits used were derived from mixed New Zealand and Flemish strains, and were maintained on a ration of complete rabbit chow, supplemented several times weekly with raw carrots and lettuce

The substances injected were prepared as follows

1 *Extracts* The extracts used in Experiments 3 and 5 were prepared according to the method of Annersten The long bones were excised from freshly killed rabbits (approximately three months old in Experiment 3, and five months old in Experiment 5), and were crushed to a pulp in a hand mill A tissue mincer was used to prepare the pulp for the extracts of skeletal muscle About 2 5 cubic centimeters of extraction fluid (100 cubic centimeters of 95 per cent alcohol plus 5 cubic centimeters of tenth-normal hydrochloric acid) was added to each gram of pulp and the mixture was rotated in a gentle shaker for about twenty hours (some at room temperature, some at 1 degree centigrade) The mixture was centrifuged, the supernatant fluid was decanted and concentrated to about one-half its volume in an air stream at 32 to 35 degrees centigrade (Experiment 3) or in a vacuum desiccator (Experiment 5) In Experiment 5, the extract was passed through a

Seitz filter prior to concentration. The concentrated extracts were mixed with an equal volume of normal saline immediately before injection, from 3 to 5 cubic centimeters of this mixture per muscle was injected.

2. *Alcohol.* Commercial 95 per cent. ethanol was diluted to 40 per cent. by volume with sterile distilled water. In Experiment 1, the alcohol was acidified with hydrochloric acid (100 cubic centimeters of 40 per cent. alcohol plus 5 cubic centimeters of tenth-normal hydrochloric acid).

3. *Calcium Chloride.* One or 2 per cent. aqueous calcium chloride was sterilized by autoclaving.

4. *Autogenous Blood.* In Experiment 6, blood was obtained by sterile heart puncture, and was injected intramuscularly before it clotted.

5. *Ammonium Chloride.* Sterile 1 per cent. ammonium chloride was employed in Experiment 10.

The various substances were injected under sterile precautions by multiple-puncture infiltration into the triceps and quadriceps. A different 22-gauge needle was used for each muscle, and contact with the skeletal system was avoided. In Experiment 3, the needle was inserted mainly into the mid-portion of the muscle, in Experiments 4 and 5, mainly into the distal portion. In Experiments 6, 7, and 8, it was inserted in half of the animals in the mid-portion, in half, in the distal portion, while in Experiments 9 and 10, the single injection was made into the mid-portion. Although not specifically stated by Levander or Annersten, it is likely that the rectus femoris muscle which they injected was the second or posterior portion of the rectus femoris, as described by Bensley. Martin Lagos and Zarapico Romero, on the other hand, stated that they injected into the anterior rectus muscle of the thigh. We have in our later experiments attempted to infiltrate especially the second or posterior portion. However, it was evident from the extent of the lesions and from roentgenographic studies, made after intramuscular infiltration with radio-opaque material (diodrast), that considerable spread of the injected substance throughout the muscle occurs regardless of the primary site of injection. In view of this, the location of the lesions should be given more emphasis than the location of the injection site.

The duration was considered the period from the first injection (or pre-injection) of an irritant solution into the muscles to the time the muscles were excised. This period varied from nineteen to thirty days (with an average of twenty-five). The earlier and later stages of the reactions have not been studied in this investigation.

After sacrifice of the animals, the muscles were examined roentgenographically *in situ* and after excision. Transverse incisions were made about 5 to 8 millimeters apart and extending almost through the muscle. Fixation in Zenker-formol mixture for twenty-four hours was followed by washing for twenty-four hours in running tap water. Slices, 2 to 5 millimeters thick, were numbered consecutively from the insertion of the muscle. The slices were stored in 70 per cent. alcohol and placed in water for several hours prior to sectioning. Tissues which roentgenographically seemed to contain bone were usually decalcified in 6 per cent. sulphosalicylic acid for forty-eight hours, and then washed in water for twenty-four hours. From each slice, sections of about 25 to 50 micra in thickness were cut on a freezing microtome. These were mounted from 50 per cent. alcohol onto slides, previously covered with a thin film of 2 per cent. gelatin. The sections were stained with Wright's stain (1.5 grams of Wright's stain in 500 cubic centimeters of absolute methyl alcohol), dehydrated, cleared in xylol, and mounted in clarite.

RESULTS

The lesions were usually visible grossly as necrotic areas in the muscles, often chalky in appearance, firm to palpation, and opaque to transillumination. In some instances, discrete, hard nodules were palpable which proved to be chondro-osseous tissue. Gritty material frequently was encountered by the knife when slicing the fresh muscle.

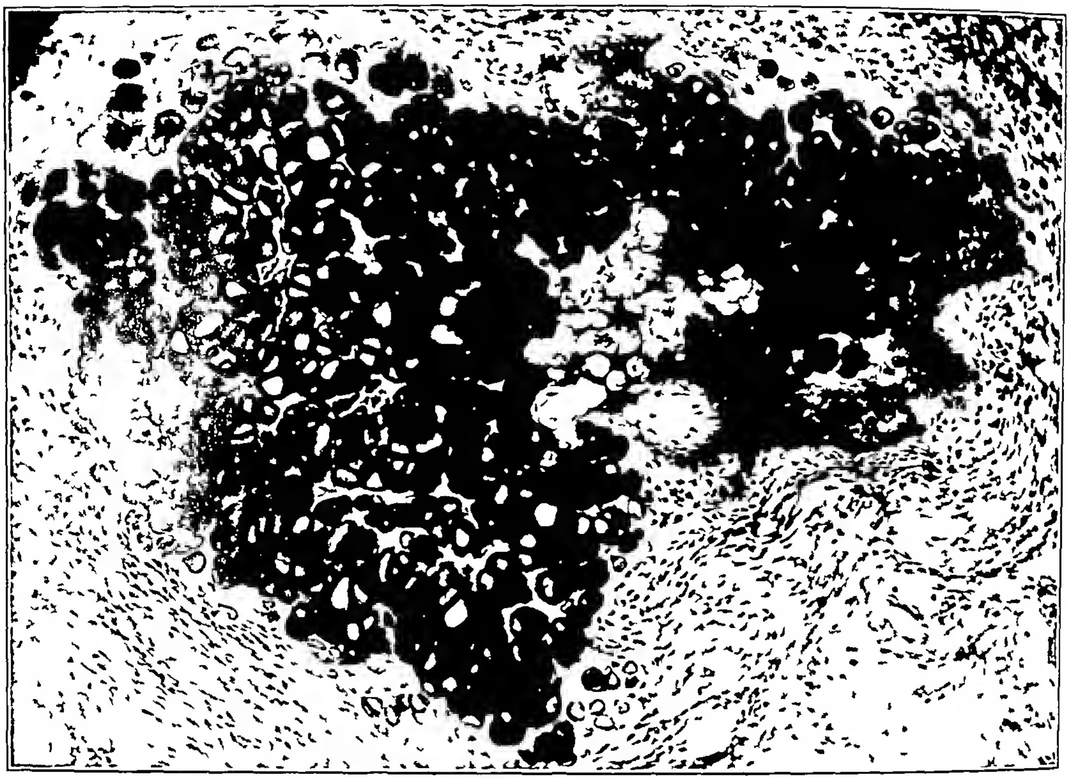

FIG 1-A

Experiment 6, Rabbit 50 Cartilage occurring in the left triceps twenty-three days after a single injection of 40 per cent alcohol (× 90) New bone can be observed at the lower right margin of the cartilage, endochondral replacement has begun in the central portion Celloidin section, stained with hematoxylin and eosin

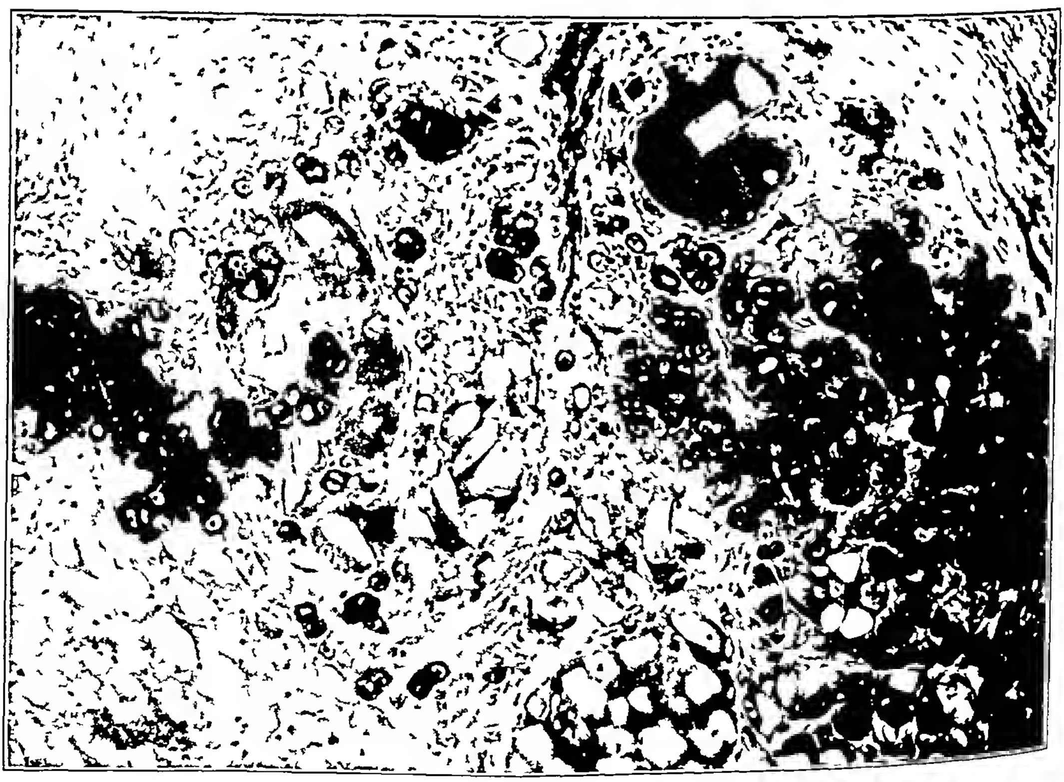

FIG 1-B

Cartilage occurring in the left triceps of the same rabbit, twenty-three days after a single injection of 40 per cent alcohol (× 110) Cartilage cells, often isolated, can be seen in the connective tissue between the muscle fibers Celloidin section, stained with hematoxylin and eosin

The histological appearance was that which is seen after the injection of any necrotizing or irritating solution. Centrally, in the more severely injured regions, the muscle fibers and the connective tissue lying between them were necrotic. No nuclei were visible in the pink-staining muscle fibers, and there was no evidence of proliferation of connective tissue here. Peripherally, where the damage was less, there was a widespread proliferation of connective tissue which extended between the muscle fibers. Here, some of the muscle fibers were necrotic and some were calcified, some showed multinucleate giant cells, while others appeared normal. Nodules of fibrous tissue, such as those seen in the organizing stage of granulation tissue, were observed frequently where the lesion had involved the fasciae, tendons, or larger intermuscular septa.

Cartilage occurred in the newly proliferated connective tissue, either as discrete nodules of hyaline cartilage (Fig. 1-A) or as aggregations of isolated, encapsulated cartilage cells (Fig. 1-B). The cartilage was situated between the muscle fibers, adjacent to the dense fasciae or tendons or, occasionally, within the dense fascia. Endochondral ossification was observed frequently. After injection with alcohol alone or with calcium chloride, intramuscular nodules of chondro-osseous tissue were produced (Fig. 2-B). Enchondral replacement of these cartilage nodules by bone may produce a structure resembling the cortex and medulla of a tubular bone. Hematopoietic and fatty marrow often are present.

Granular crystalline deposits of lime salts, identified by the von Kossa method, were often observed. Such deposits were found in muscle fibers, in nodules of connective tissue, in the dense fasciae, and in the subcutaneous tissue. There appeared to be no mutual dependence between these deposits of lime salts and the newly formed cartilage and bone, although the two were occasionally observed in juxtaposition.

The reactions after injection of calcium chloride differed from those following alcohol (in the concentrations compared) mainly in the degree of necrosis. The calcium chloride produced more necrosis, and was followed by more intense calcification. No radio-opacity was observed immediately after infiltrating a muscle with 2 per cent. calcium chloride.

In Table I, the experiments have been summarized and the number of muscles satisfactorily injected (that is, without gross suppuration) have been compared with the number of muscles which were positive (that is, contained pre-cartilage, cartilage, or bone). After the injection of alcohol alone, twenty-three of thirty-seven triceps (62 per cent.) and twelve of forty quadriceps (30 per cent.) were positive. Two of twenty-seven triceps and seven of twenty-nine quadriceps were positive after injection of calcium chloride.

The relationship of the histological sections to the origin and insertions of the muscles is diagrammatically represented in Tables II and III, the location of cartilage and bone being superimposed upon the extent of the lesions. There was a greater tendency for pre-cartilage, cartilage, or bone to lie nearer to the origin and insertion of the muscles than in the mid-portion. No instance of direct connection of the newly formed bone with the skeleton was observed. While the tables depict only the muscles which were positive, there were many others with fibrous proliferation but not cartilage or bone formation.

In Experiments 9 and 10, the cartilage or bone which formed proximally in the muscles occurred more frequently in certain locations. In eight muscles (six rabbits), bone or cartilage was found in, or adjacent to, the posterior portion of the rectus femoris, next to the dense, vertical fibrous septum situated in the mid-portion of the muscle. Similarly, the fascia which surrounds the muscle was a favorite site for chondrification (Fig. 2-B). In six, cartilage or bone was located in the long head of the triceps. Five of these showed chondro-osseous metaplasia near the dense fascia on the medial border of the muscle.

The sex of the animals appeared to have no relationship to the incidence of pre-cartilage, cartilage, or bone formation. Satisfactory lesions (the various irritants listed in Table I being used) were produced in ninety-one muscles in male animals, with thirty positive results (33 per cent.). Of seventy-six muscles in females, twenty-six positive results (34 per cent.) were obtained.

TABLE 2

EXP NO	RABBIT NO	SEX	AGE-MONTHS	SIDE-R,L	SUBSTANCE PRE-INJECTED	SUBSTANCE INJECTED	NO INJECTIONS	EXERCISE	STILBESTROL	DURATION-DAYS	1	2	3	4	5	6	7	8	9	10	11	12	13
3	24	F	3-4	L	-	EX M	3	-	-	23	C	C	▨	▨	▨	▨	▨		▨				
	26	M	"	L	-	EX M	"	-	-	23	C	PC	▨	▨	▨	▨	▨	▨					
	28	F	"	L	-	EX M	"	-	-	19	C	▨	▨	▨	▨	▨	▨						
	31	F	"	R	-	EX B	"	-	-	22	C	C	C	▨	▨	▨	▨						
	32	M	"	R	-	EX B	"	-	-	22	C	▨	▨	▨	▨		▨						
	"	"	"	L	-	EX M	"	-	-	22	PC	C		▨	▨								
	37	F	"	L	-	EX M	"	-	-	22	PC	C	PC	▨	▨	▨	▨	N					
4	38	F	3-5	R	ALC	AC ALC	1	-	-	24	▨	C	C	B	▨	▨	▨	▨	▨	▨	▨	▨	▨
	39	F	"	"	"	"	"	-	-	"	PC	PC	▨	▨	▨	▨	▨						
	40	F	"	"	"	"	"	-	-	"	▨	PC	▨	PC	▨	▨	▨	▨	▨	▨	▨		
	41	M	"	"	"	"	"	-	-	"	C	CB	C	C	PC	▨	▨	▨					
	42	M	"	"	"	"	"	-	-	"	RC	C	C	C	▨	PC	▨	▨	▨	▨			
	43	M	"	"	"	"	"	-	-	"	C	C	▨	▨	▨	▨	▨	▨	▨	▨			
5	44	F	5+	L	ALC	ALC	3	-	-	27	PC	▨	▨	▨	▨								
	45	F	"	R	"	EX B	"	-	-	"		PC		▨		▨		▨					
	49	M	"	R	"	"	"	-	-	26		C		C		CB		PC					
	"	"	"	L	"	ALC	"	-	-	"	C		▨		C			▨		▨			
6	50	M	2−	L	-	ALC	1	-	-	23	N	▨	CB	C	▨	▨	▨	N	N	N			
	52	M	"	L	-	"	"	-	-	"	N	▨	▨	▨	CB	C	▨	N					
7	55	F	3-4	L	-	ALC	3	-	-	30	PC	▨	▨	▨	▨	▨	▨	▨	▨	▨			
	56	F	"	L	-	ALC	"	+	-	"	▨	C	▨	▨	▨	▨	▨	▨	▨	▨			
	57	F	"	R	-	$CACL_2$	1	+	-	21	▨	CB	CB	CB	CB	CB	C	C	C	▨	C	▨	
	"	"	"	L	-	ALC	3	+	-	30	▨			C	C	C	▨	▨	▨	▨	C	▨	
	58	M	"	L	-	ALC	"	+	-	"	PC	PC	PC	C	▨	CB	CB						
8	63	M	3	L	-	ALC	2	-	+	26	▨	PC	▨	▨	▨	▨	M	M	N				
	66	F	"	"	-	"	"	-	+	26	PC	▨	▨	▨	▨	▨	▨	N					
	69	F	"	"	-	"	"	-	-	25	C	C	▨	▨	▨	▨	▨	▨	▨	▨	N		
9	72	M	1+	L	-	ALC	1	+	-	28	M	▨	▨	▨	▨	▨	C	▨	▨				
	74	F	"	"	-	"	"	+	+	"	M	▨	▨	▨	C	C	CB	C					
	76	M	"	"	-	"	"	-	+	"	M	C	▨	▨	▨		▨	C	M				
	77	M	"	"	-	"	"	+	+	"	M	▨	C	C	▨	N	N	N					
	78	M	"	"	-	"	"	-	+	"	N	M	▨	▨	▨	▨	C	C					
	"	"	"	R	-	$CACL_2$	"	"	+	"	M	PC	▨	▨	▨	▨	▨	▨					
	81	M	"	L	-	ALC	"	-	-	"	▨	▨	▨	▨	▨	CB	CB	CB	CB				

TRICEPS

← INSERTION ORIGIN →

NUMBER OF MUSCLE-SLICE

PC = PRECARTILAGE
C = CARTILAGE
B = BONE
▨ = GOOD LESION

M = MILD LESION
N = NO LESION
☐ = NOT SECTIONED

EX M = EXTRACT OF MUSCLE
EX B = EXTRACT OF BONE
ALC = 40% ALCOHOL
AC ALC = HCl-ALCOHOL

Diethylstilbestrol, administered intramuscularly every other day in 2-milligram dose did not influence the production of metaplastic cartilage and bone Eleven of thirty-six animals so treated (31 per cent) had positive results In the control animals, thirteen of thirty-seven (35 per cent) had positive results The amount of cartilage or bone was the same in both groups

In general, young animals tended to form larger and more widespread areas of meta-

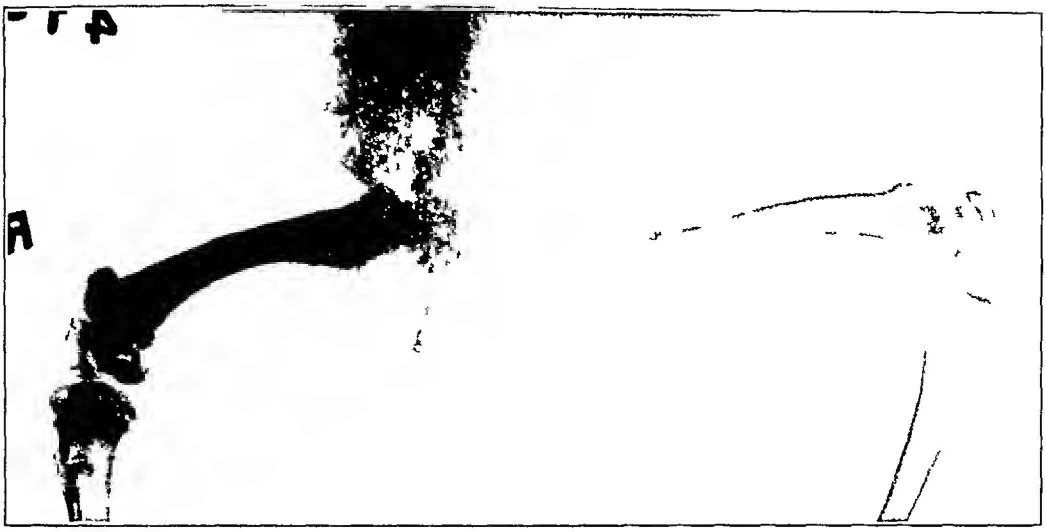

Fig. 2-A

Experiment 9, Rabbit 81. Two nodules of chondro-osseous tissue are evident in the proximal portion of the left quadriceps. Intramuscular and subcutaneous calcifications are especially evident in the right limb. Roentgenogram taken twenty-eight days after the injection of 40 per cent. alcohol on the left and 1 per cent. calcium chloride on the right. The histological appearance of the two nodules is shown in Fig. 2-B.

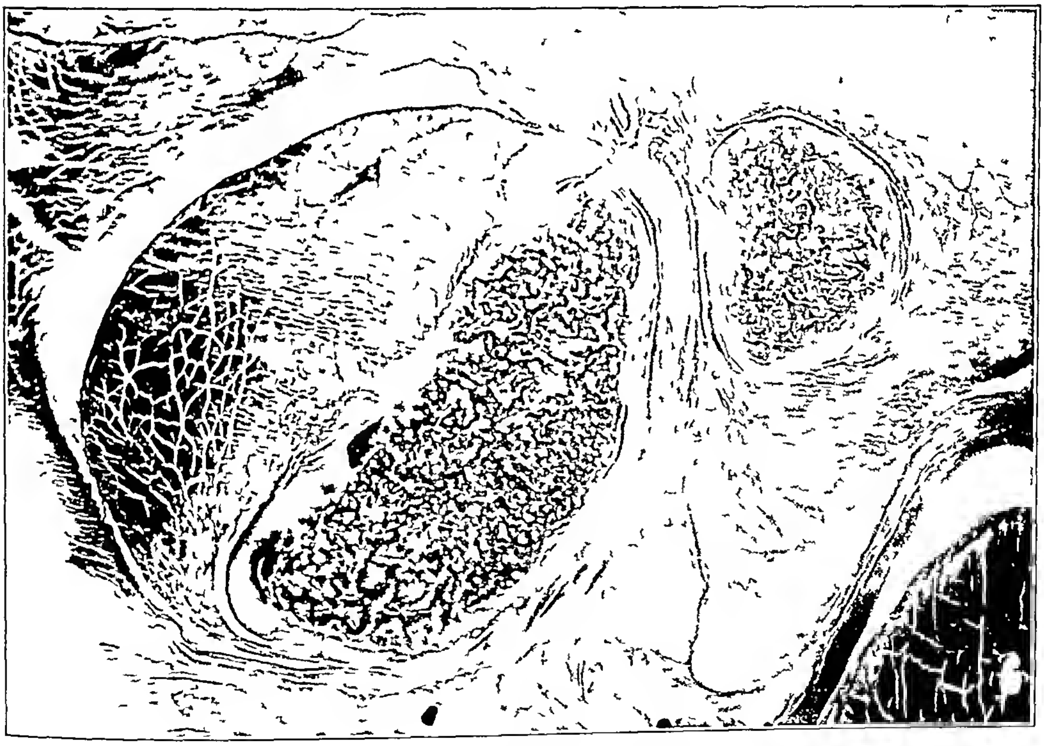

Fig. 2-B

Large nodule of chondro-osseous tissue (× 11) in the proximal end of the posterior portion of the rectus femoris, occurring twenty-eight days after one injection of 40 per cent. alcohol. The nodule lies adjacent to the dense fibrous septum which extends down the middle of this muscle. A smaller nodule is seen in the contiguous muscle. Frozen section, Wright's stain.

plastic cartilage and bone. In Experiments 6, 9, and 10, the animals were less than two months old, and were appreciably smaller than those in the other experiments. Of fifty muscles with adequate lesions, twenty-one gave positive results (42 per cent.). On the other hand, of 117 muscles in the older animals, thirty-five positive results (30 per cent.) were obtained.

TABLE 3

EXP NO	RABBIT NO	SEX	AGE-MOS	SIDE-R,L	SUBSTANCE PRE-INJECTED	SUBSTANCE INJECTED	NO INJECTIONS	EXERCISE	STILBESTROL	DURATION-DAYS	QUADRICEPS ←INSERTION ORIGIN→ NUMBER OF MUSCLE-SLICE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
3	26	M	3-4	R	ALC	EX B	3	-	-	29	C	C	▨	▨	▨		▨	▨								
	27	F	"	R	"	"	"	-	-	"	▨	PC	▨	▨	▨	▨	▨	▨								
5	44	F	5+	R	"	"	"	-	-	27	C	▨	▨	▨				▨								
6	50	M	2-	L	-	ALC	1	-	-	23	PC	C	▨	▨	▨	▨	▨	▨								
7	55	F	3-4	L	-	ALC	3	-	-	30	PC	▨	PC	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨		
	57	F	"	R	-	CACL2	1	+	-	21	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	CB	CB	CB	CB	
	"	"	"	L	-	ALC	3	+	-	30	▨	PC	▨	▨	▨	▨	▨	▨	CB	C	CB	CB				
	58	M	"	R	-	CACL2	1	+	-	21	M		▨		▨		▨		▨	▨	CB	CB	▨	▨	▨	
8	66	F	3	R	-	CACL2	2	-	+	26	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	C	▨	▨	▨	▨
	68	M	"	L	-	ALC	"	-	-	21	N	▨	▨	▨	▨	▨	▨	▨	▨	▨	C	N				
	69	F	"	L		"	"	-	-	25	N	N	▨	▨	▨	▨	▨	PC	C	▨	▨	N				
9	71	M	1	R	-	CACL2	1	+	-	28	M	▨	▨	▨	▨	▨	▨	▨	C							
	"	"	"	L	-	ALC	"	+	-	"	▨	▨	▨	▨	▨	▨	CB	PC	▨							
	72	M	"	L	-	"	"	+	-	"	C	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨					
	73	F	"	L	-	ALC	"	-	-	"	PC	▨	PC	▨	▨	▨	▨	▨	M	M	N					
	74	F	"	L	-	"	"	+	+	"	C	PC	▨	▨	▨	▨	▨	▨	M							
	77	M	"	R	-	CACL2	"	+	+	"	M	M	M	▨	▨	M	▨	C	M							
	"	"	"	L	-	ALC	"	+	+	"	C	C	▨	▨	CB	CB	▨	N								
	80	M	"	L	-	"	"	-	-	"	▨	▨	▨	▨	CB	CB	B		M	M						
	81	M	"	L	-	"	"	-	-	"	▨	▨	▨	▨	C	▨	CB	▨	N							
10	82	F	"	R	-	CACL2	"	+	-	"	▨	▨	▨	▨	▨	▨	CB	▨	M							
	84	M	"	R	-	CACL2	"	+	-	"	▨	▨	▨	▨	▨	▨	CB	CB	B							

PC = PRECARTILAGE
C = CARTILAGE
B = BONE
▨ = GOOD LESION

M = MILD LESION
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ALC = 40% ALCOHOL
AC ALC = HCl-ALCOHOL

Forced exercise of animals after injection of the irritant substances increased the incidence of bone and cartilage formation, also, the amount of chondro-osseous substance tended to be greater in the exercised animals In Experiments 7, 9, and 10, some of the animals were exercised in a rotating cylindrical cage Of thirty-nine adequately injected muscles in the exercised rabbits, eighteen (46 per cent) gave positive results, as compared with eight of thirty-five (23 per cent) for the non-exercised controls From Tables II and III, the widespread incidence of cartilage and bone in the muscles of some of the exercised animals can be noted In animal 57, which was exercised intensively, both triceps and quadriceps contained cartilage, either alone or in combination with bone, which was more widely distributed in multiple foci than was seen in any other experiment

DISCUSSION

On the basis of the results of these experiments and those cited from the literature the existence of a specific osteogenetic substance in alcoholic extracts of cartilage and bone has not been established Cartilage or bone has been obtained by the injection of non specific substances Although Levander, Annersten, and Bertelsen obtained no bone or cartilage in animals injected with alcohol alone, Martin Lagos and Zarapico Romero obtained positive results in seven of eighty-seven rabbits (8 per cent) Annersten obtained positive results in one animal injected with extract of tendon, in one, with extract of

muscle, and in two, with a calcium-phosphorus-alcohol mixture. Bone and cartilage occurred in one of Bertelsen's controls which had been injected with extract of liver. In the experiments reported here, cartilage and bone, alone or in combination, were produced in twenty-three of twenty-seven triceps (62 per cent.) and in twelve of forty quadriceps (30 per cent.) by the intramuscular injection of alcohol alone.*

The criteria for positive results have not been uniform among workers in this field. Many of the illustrations of Levander and Annersten show unmistakable mature cartilage and bone. Annersten presents an illustration (page 41), showing a transition stage between young connective tissue and early cartilage. For the calculation of positive results, he does not state at what stage in this transition he considered a tissue to be cartilage. Such a decision is often difficult. Bertelsen, who obtained cartilage or bone in twenty-nine of sixty injected muscles, states (page 165): "The changes, however, were as a rule limited to small islands or streaks in the excised tissues, they were sparse, but still very characteristic. Apart from one or two cases, however, the cartilage found was not 'mature', large-celled, but small-celled of foetal type with connective-tissue-like cells." In our sections, too, there appeared an intermediate tissue in which the matrix took a pale blue-green color with Wright's stain and was larger in amount than in typical fibrous tissue. This tissue was similar to early cartilage, and was often seen near areas of mature cartilage. However, since it was also observed often in these muscles without mature cartilage, it has not been considered "pre-cartilage" in evaluating results. Early capsules have been evident in the tissue we have classified as "pre-cartilage".

While the mechanism of this reaction is completely unknown, all workers agree that injury sufficient to cause proliferative repair is essential. Levander[13] obtained negative results in ten muscles injected with aqueous extracts of bone. Oily extracts, which caused little cellular proliferation, proved negative for Annersten. In our experiments, autogenous blood, which was resorbed with very little reaction, yielded negative results. Levander and Annersten emphasized the necessity of obtaining sufficient organizing connective tissue, and, in testing many of their extracts, they used a "pre-injection" of 40 per cent. alcohol to obtain this. Likewise, all agree that extensive necrosis, especially if accompanied by suppuration, is detrimental to the formation of ectopic bone and cartilage. Annersten has emphasized this point. In spite of extensive proliferation of connective tissue at the periphery of abscesses, bone and cartilage did not form in such regions in any of our animals.

It is self-evident that a minimal amount of time must elapse following the injury for bone or cartilage to appear. Although Annersten reported three positive results at eight, nine, and eleven days, by far the majority of his positive results were obtained in animals killed seventeen days or longer after injection. The sacrifice of his controls injected with alcohol alone, or with alcoholic extracts of autoclaved bone, ten days after injection (with negative results), may have allowed too short a time interval. Levander did not state the time intervals for any of his controls, all of which were negative.

Whereas the age of the animals is an important consideration in evaluating results, neither Annersten nor Levander stated the age or weight of the test rabbits used. Annersten did mention that the extracts were prepared from rabbits three to six months old.

We have observed cartilage remnants in all instances in which bone was found, and have never observed bone alone. Therefore, we believe that the primary tissue found in this intramuscular ossification is cartilage, with subsequent appearance of bone both by endochondral replacement and by intramembranous ossification. With alcohol alone or with calcium chloride, we have obtained intramuscular nodules of chondro-osseous tissue, which show as much organization as that which Lacroix[11,12] ascribed to his alcoholic extracts of epiphyses of younger rabbits (Fig. 2-B).

* Since this article was submitted, Hartley, Tanz, and Schneider have reported that bone occurred in three of eleven mature rabbits, fifty-three days after the injection into the thigh muscles of alcoholic extract of the ends of the long bones of young rabbits.

It is unfortunate that the search for the hypothetical substance has been confined largely to the rabbit *, since this species has manifested a high incidence of ectopic cartilage and bone in many organs, following a wide variety of experimental procedures. Selye obtained cartilage or bone in five of fifteen rabbits (33 per cent.), following repeated intramuscular injections of quinine hydrochloride. Cartilage or bone has been observed in the muscles of rabbits, following injections of calcium chloride [19], following traumatization [6, 7, 16], and following traumatization plus injections of bone autolysates [19]. After injection of formic acid into the vitreous body, Imai found bone in the eyes of twelve of twenty-six rabbits (46 per cent.). Engelstad observed that roentgen irradiation, sufficiently intense to cause degenerative pulmonary changes, was followed by bone formation in the lung of fifteen of twenty-eight rabbits (53 per cent.). After application of silver nitrate or copper sulphate to the abdominal aortae of ten rabbits, Harvey obtained bone in five and osteoid tissue in three.

The claim of Blum that locally injected phosphatase leads to the formation of ectopic bone is open to question. His alginate gel-phosphatase mixtures contained a highly irritant concentration of calcium chloride. Since von Seemen stated that Goto had obtained ectopic bone in rabbits by the injection of calcium chloride, and since we have obtained bone or cartilage, or both, in two of twenty-seven triceps and seven of twenty-nine quadriceps with calcium chloride, it seems probable that this is the responsible ingredient in Blum's mixtures rather than the injected phosphatase.

SUMMARY

1. Following intramuscular injection into rabbits of alcohol alone, twenty-three of thirty-seven triceps (62 per cent.) and twelve of forty quadriceps (30 per cent.) contained cartilage or bone, alone or in combination.

2. Two of twenty-seven triceps and seven of twenty-nine quadriceps contained cartilage or bone or both, following injection of calcium chloride.

3. There is a greater tendency for pre-cartilage, cartilage, and bone to form near the origin or the insertions of muscles than in the mid-portions.

4. Younger animals (one month old) formed larger amounts of more mature cartilage and bone than older rabbits, following injection of alcohol alone or of calcium chloride.

5. There was no appreciable difference in the frequency of bone and cartilage on the basis of sex.

6. Diethylstilbestrol, in the dosages used, did not influence the course of the intramuscular reactions.

7. The incidence and extent of intramuscular cartilage and bone was increased by exercising the animals.

8. Intramuscular cartilage and bone formation was not observed if suppuration occurred as a result of the injection of the irritant solutions.

CONCLUSIONS

1. In the rabbit, ectopic chondrification and ossification frequently follow intramuscular injection of irritating substances,—such as alcohol, calcium chloride, or mixture which contain these irritants.

2. Intramuscular injection of extracts of bone, cartilage, or muscle does not produce cartilage or bone more frequently or more extensively than does the extracting fluid alone. The existence of a specific osteogenetic substance ("osteogenin") in extracts of skeletal tissue cannot be accepted as proved.

NOTE: The authors wish to thank Franklin C. McLean, M.D., and C. Howard Hatcher, M.D., for their advice and suggestions throughout the course of this investigation.

* Recently Pfeiffer has injected alcoholic osseous extracts into the testes of mice, but has obtained no cartilage or bone.

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THE GROWTH OF THE BONE MARROW *

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Among the numerous papers on bone marrow listed in the *Index Medicus*, only that of Huggins and Smith is concerned with the question of how marrow grows, as compared with growth of the other parts of the bone These authors stated that, following intravenous injection, thorium dioxide becomes firmly fixed in the bone marrow, in the young animal, subsequent areas of marrow growth are thorium-free, allowing recognition of the new tissue by roentgenographic and histological techniques The conclusion is drawn that the bone marrow increases in length principally at the metaphyses, and grows in thickness at its circumference

The author has repeated these experiments, and the results, while confirming in the main the conclusions of Huggins and Smith, include additional information which may be worth recording

EXPERIMENTS

Ten six-week-old rabbits were injected intravenously with an electronegative thorium sol (thorotrast), containing approximately 25 per cent of thorium dioxide At two day intervals, they received four injections totaling 10 cubic centimeters, or about 20 cubic centimeters per kilogram No immediate ill effects were observed, it is well known that some months elapse before the toxicity from this substance develops

On the day the injections were completed, the medullary cavity seemed blurred on the roentgenographic film One of the animals was sacrificed and examined histologically Scattered among the other cells, the histiocytes of the marrow were found to have accumulated particles of thorium The growth of the other nine animals has been observed and identical results have been noted in all

Four days after the last injection (Fig 1-A), a clear area began to appear in the marrow about the shadow of the thorium-laden portion of the tibia This shadow had the same shape the medullary cavity had had a few days before Thirty days later (Fig 1 B) the clear zone had enlarged everywhere The shadow had kept its transverse diameter but had definitely increased in length

It is difficult to decide, even with the aid of histological examination, whether the longitudinal growth is the result of intussusception all over the marrow or, as the presence of a central lacuna suggests, of the formation of new tissue at the place where the nutrient artery enters the marrow

The same description applies to the other bones In the radius and ulna (Figs 2-A and 2-B) the inequality of growth between the fore legs and hind legs emphasize the following observation The clear zone between the end of the medullary shadow and the end of the medullary cavity enlarges, in each case, at a rate which is exactly proportional to the rate of growth of the neighboring epiphyseal cartilage

DISCUSSION

The evidence given here can only concern the growth of the marrow, inasmuch as the thorium-laden cells may be assumed to remain in the same place from the beginning to the end of the experiment Lambin has shown that the marrow attempts to get rid of the histiocytes which have accumulated particles of thorium, they slowly migrate, he says, toward the axial region of the marrow

* Received for publication November 18, 1948

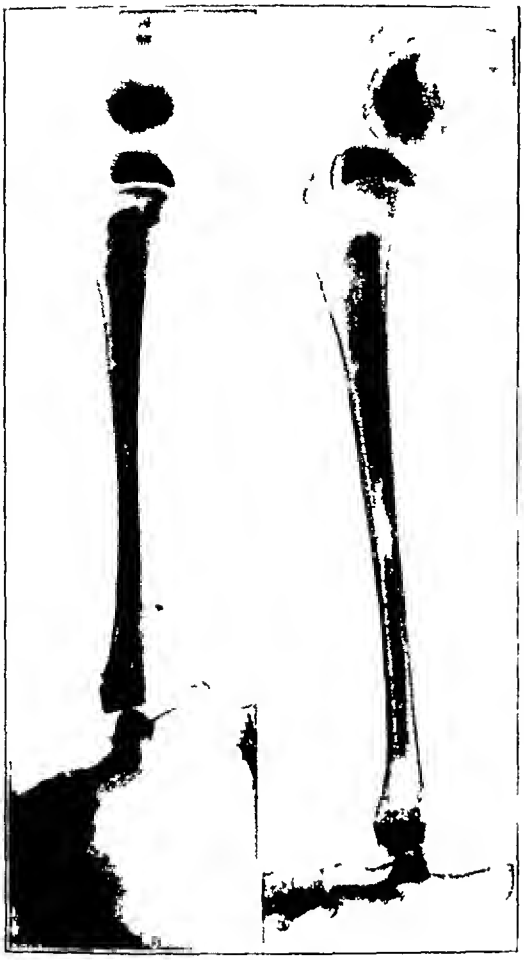

Fig. 1-A Fig. 1-B

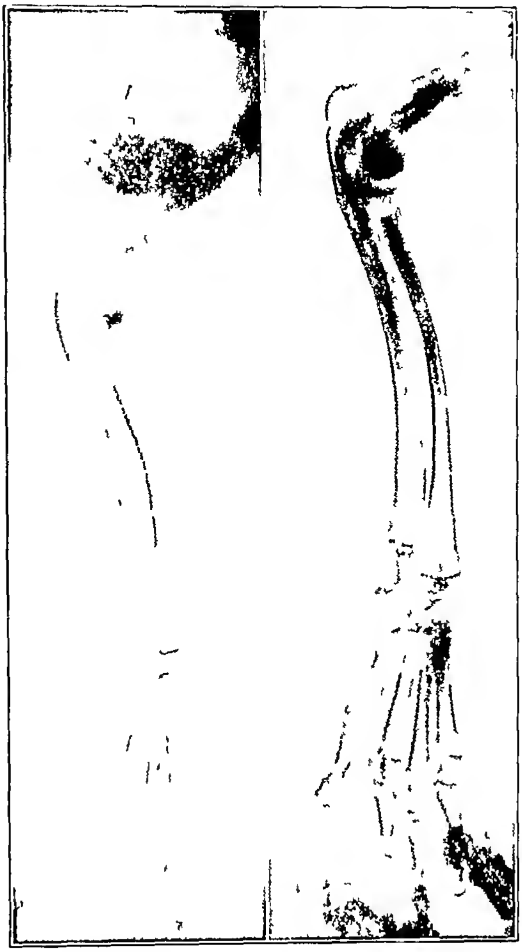

Fig. 2-A Fig. 2-B

Fig. 1-A. Roentgenogram of the tibia of a young rabbit, four days after completion of intravenous injections of thorotrast. A clear area has begun to appear about the thorium-laden portion of the marrow.

Fig. 1-B. Thirty days later, the clear area has enlarged and the medullary shadow is definitely longer.

Fig. 2-A. Same experiment. Roentgenograms of radius and ulna, four days after last injection.

Fig. 2-B. Thirty days later, the clear zone around the medullary shadow has enlarged and the shadow itself has increased in length.

We think, nevertheless, that the roentgenograms of Huggins and Smith, together with ours, may be considered as giving a true picture of the way marrow grows, provided only those roentgenograms are compared which have been taken at brief intervals. Our principal reason for this belief is that there is an accurate relationship between the rate of growth of a given epiphyseal cartilage, on the one hand, and the rate at which the same cartilage grows away from the medullary shadow, on the other hand. The alternative explanation would be to admit a migration of the histiocytes, different in rate and in direction in every case,—an explanation which must obviously be discarded.

We may conclude, therefore, that the bone marrow grows by a combined process of peripheral addition of new tissue and interstitial growth. (When speaking of interstitial growth, however, we must leave unanswered the question of whether we deal with uniform intussusception or with a kind of breaking up in fragments which have subsequently drifted apart.) The growth of the marrow thus appears as intermediate between the growth of the bone tissue, which is exclusively a peripheral effect, and that of the periosteum, which is interstitial[2].

Huggins and Smith emphasized the peripheral growth of the marrow, but neglected its interstitial growth. In the roentgenograms of the knee, illustrating their paper, neither the femur nor the tibia is shown in its entirety. It will appear from the present study that

a more complete picture of the phenomenon is gained by a comparison of bones which have been x-rayed in their entire length

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EXPERIENCES IN THE USE OF HOMOGENOUS (BONE BANK) BONE*

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The use of homogenous bone grafts is not new, reports concerning these grafts hav appeared in the literature from time to time The impetus for the modern use of preserve homogenous grafts was probably given by Inclán's report, published in 1942, aided by th tremendous strides in the manufacture of "deep-freeze" equipment and in research co cerning the freezing and storing of foods At present many clinics, both in this country an abroad, are experimenting with homogenous grafts, usually preserved by freezing an storing in a so-called bone bank Optimistic reports have already been made[1,2,4], b they give scant attention to the use of massive grafts, particularly in the repair of no union of fractures

It is the purpose of this paper to present a report of forty-nine operations upon fort six patients in whom homogenous bone, preserved in a frozen state, was used for graftin This series includes all patients operated upon between July 1, 1946, and September 1 1948, whose end result, as regards success or failure of the graft, is known

SELECTION OF CASES

No attempt was made to select favorable cases Frozen homogenous bone was u for all patients in need of bone-grafting, who presented themselves during the period of this study Patients entering the Medical Center are, as a rule, referred because of pr vious failures and complications, or because of the severity of the condition and the ge erally unfavorable prognosis Of the forty-six patients in this series, ten had had a total o sixteen previous bone-graft operations, all with autogenous bone and all failures Twenty three patients had each had from one to four operations, other than bone-grafting, at th site of subsequent surgery, and sixteen patients had had gross infection at the operat site In evaluating the results, these figures should be borne in mind The prime objec this study was to put the use of preserved homogenous grafts to a rigorous test, and i felt that in this series of cases that purpose was achieved

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Ill January 26, 1949

SURGICAL PROCEDURES

No attempt was made to follow a set pattern of operative procedure, but rather to try as many different types of grafts and techniques as the material at hand permitted Thus, massive grafts were used as onlays, inlays, bone pegs, dual grafts, and in the Phemister type of graft, both with and without the addition of bone chips The plentiful supply of donor bone permitted the trial of new procedures, such as arthrodesis of the shoulder joint in three cases, to be described All patients received prophylactic doses of penicillin, usually over a postoperative period of seven to ten days The two patients with tuberculosis received streptomycin

Most of the surgery was done by the author or by members of his house staff However, bone was used for a few cases on other services at the Medical Center, and several operations were done in other hospitals In all, there were ten operating surgeons

DONOR BONE

Procurement of Bone

Donor bone was secured from patients at operations in which bone was removed—that is, clean amputations, rib resections, et cetera—and from fresh cadavera In all instances, the donors had had negative serological findings and were free from any known nfectious disease, malignant lesion, or blood dyscrasia Cadaver bone was secured only rom young adults who had met a sudden traumatic death Bone was removed from the adaver within two hours after death and under as near operating-room technique as possible, the chief difference being that the surgery was done in the morgue rather than n an operating room

Method of Processing Bone

The bone for storage was carefully denuded of soft tissue, the periosteum being left ntact, if possible In the case of cortical bone, portions were then fashioned with a motor aw and osteotome to the proper size for use as massive grafts Carpal and tarsal bones, which were to be used as a source of cancellous bone, were stored as such Femoral conyles are an excellent source of cancellous bone, and, when available, the condyles were ectioned into portions most likely to furnish enough bone for one operation Ribs were tored singly and intact

In the first year of this study, the sectioned bone was enclosed in sterile wrappers of otton cloth and then in sterile oiled silk, and was appropriately labeled Storage was in a eep-freeze unit in which the temperature was held to minus 40 degrees centigrade by he addition of dry ice

During the second year, bone has been placed in sealed glass bottles, according to the ethod of Bush, frozen, and stored in an ice-cream-storage cabinet in which the temperaure is kept between minus 20 and minus 25 degrees centigrade There has been no noticeble difference in results between these two methods, but it is believed that Bush's method bottling is superior, because one is able to view the bone and make more accurate selecons as to the size and amount desired for a particular operation No preservative chemils, or bactericidal or antibiotic agents were used Culture studies were not done At the me of surgery, the donor bone was brought to the operating room and placed in sterile arm saline solution until used Normal saline solution is believed to have no deleterious fect upon the bone graft

In two instances, frozen bone has been shipped elsewhere, the procedure being the me as that used for shipping small quantities of ice cream The bottle containing the one is placed in a corrugated-cardboard ice-cream-shipping container and packed with y ice In both cases, more than twelve hours and less than twenty-four hours elapsed fore the bone was again placed in a deep-freeze unit The bone arrived at its destination good condition In one instance the operation was successful, after two previous failes with autogenous bone, the result is not yet known in the other case

TABLE I					
CONDITION	PART	NO.	SUCCESS	FAILURE	INFECTION
UNUNITED FRACTURES	TIBIA	9	6	3	2
	ULNA	5	3	2	0
	RADIUS	4	3	1	0
	FEMUR	4	3	1	0
	HUMERUS	2	2	0	0
	TOTAL	20	14.5 (72.5%)	5.5 (27.5%)	2 (10%)
BONE DEFECTS	TUMORS	9	9	0	0
	OSTEOMYELITIS	2	1	1	0
	TOTAL	11	10 (91%)	1 (9%)	0
ARTHRODESIS OF JOINTS	SPINE	6	6	0	0
	HIP	4	4	0	1
	SHOULDER	3	3	0	0
	ANKLE	1	1	0	0
	TOTAL	14	14 (100%)	0	1 (7.1%)
MISCELLANEOUS	BONE BLOCK	2	1	1	0
	OSTEOTOMY	2	1	1	1
	TOTAL	4	2 (50%)	2 (50%)	1 (25%)
GRAND TOTAL		49	40.5 (82.6%)	8.5 (17.3%)	4 (8.1%)

Indications for bone-grafting and results in forty-nine operations

Length of Storage Time

The length of storage time before use has varied greatly. The shortest period was three days and the longest, 308 days (ten months), both cases were successful. In seven in-stances, the storage time was over six months, the average time for the entire series was 134 days (over four months). Length of storage time apparently has had no effect on the success or failure of the graft.

In the experimental laboratory, grafts applied to rabbits, in which the bone was used after eighteen months of storage, have been successful. No attempt has been made to use bone that has been stored a longer length of time.

STATISTICAL DATA

The forty-nine operations in this survey have been analyzed as to the indications for bone-grafting, the success, failure, or complication of infection being noted in each case. An operation for non-union at times involved two bones, such as the radius and ulna, hence the total number of bones operated upon is greater than the number of operations (Table I). For the same reason, fractions appear in the totals. In one operation, a graft of the radius and ulna was done with resultant union of the radius and non-union of the ulna. Thus, one-half unit was allowed for each success or failure.

Of the nine tumor cases, eight were either giant-cell tumor or solitary cyst, and one was metastatic carcinoma.

TABLE 2					
TYPE OF GRAFT	CONDITION	NO	SUCCESS	FAILURE	INFECTION
MASSIVE	NON UNION	13	9 5	3 5	2
	BONE DEFECTS	2	1	1	0
	ARTHRODESIS	4	4	0	0
	MISCELLANEOUS	4	2	2	1
	TOTAL	23	16 5 (71 8%)	6 5 (28 2%)	3 (13%)
COMBINATION	NON UNION	7	5	2	0
	BONE DEFECTS	3	3	0	0
	ARTHRODESIS	5	5	0	0
	TOTAL	15	13 (86 7%)	2 (13 3%)	0
CHIP	BONE DEFECTS	6	6	0	0
	ARTHRODESIS	5	5	0	1
	TOTAL	11	11 (100 %)	0	1 (9%)
GRAND TOTAL		49	40 5 (82 6%)	8 5 (17 3%)	4 (8 1%)

Type of graft employed and results

The arthrodesing operations of the spine were performed for either scoliosis or spondylolisthesis Fusion of the hip was done on one patient with tuberculosis, the other fusion operations were done for painful arthritis In one case each of tuberculosis, flail joint, and chronic recurrent dislocation, fusion of the shoulder was done

In the miscellaneous group, the two bone-block procedures were the Thompson operation to hold the thumb in abduction The two osteotomies were for the correction of deformity of the tibia, in each case a rib was placed beneath the periosteum, on the posterior surface of the tibia

TABLE 3					
DONORS	CONDITION	NO	SUCCESS	FAILURE	INFECTION
FRESH CADAVER	NON UNION	9	7 5	1 5	1
	BONE DEFECTS	5	5	0	0
	ARTHRODESIS	3	3	0	1
	TOTAL	17	15 5 (91 2%)	1 5 (8 8%)	2 (11 7%)
PATIENTS	NON UNION	11	7	4	1
	BONE DEFECTS	6	5	1	0
	ARTHRODESIS	11	11	0	0
	MISCELLANEOUS	4	2	2	1
	TOTAL	32	25 (78 1%)	7 (21 9%)	2 (6 2%)
GRAND TOTAL		49	40 5 (82 6%)	8 5 (17 3%)	4 (8 1%)

Comparison between donor bone from patients and from fresh cadavera

Highly satisfactory results were obtained after joint fusion (100 per cent successful) and in the remedy of bone defects (91 per cent successful) However, the successes in the treatment of non-union (72 5 per cent) are not so good In the entire group, there were 82 6 per cent of successful results The infection rate was 8 1 per cent, a high figure

The same series of operations are presented in Table II, which shows the type of graft employed and the result as to success, failure, or infection As previously stated, massive grafts were used in various ways Combination grafts were those in which, in addition to a massive graft, either bone chips or "bone meal" were used with the express purpose of filling a bone defect Bone meal was made by running cancellous bone chips or ribs through a coarse meat grinder Chip grafts, as the name implies, were made up of cancellous bone obtained with the rongeur, curette, or bone cutters Bone meal is included under the category of chip graft

Although chip grafts appeared to be much more efficient, on the whole, they were used in cases with a more favorable prognosis

Table III presents a comparative study of the efficiency of donor bone from patients and that from cadavera The results indicate a higher percentage of success with the use of cadaver bone This superiority is strengthened by the fact that more than 50 per cent of the operations in which cadaver bone was used were for non-union of fractures, which are the most difficult cases On the other hand, only 35 per cent of the cases in which patient bone was used were in the non-union group It is difficult to understand how cadaver bone could be more efficient, except that it offers a method of obtaining large quantities of the particular type of bone desired The percentage of infection in the operations where cadaver bone was utilized is about twice that in the series where patient bone was used

Fig 1-A Fig 1-B Fig 1-C Fig 1-D

Case 3-F Roentgenograms show progressive healing of second graft at one-half month, two months, five months, and ten months The view at ten months (Fig 1-D) shows fracture of the graft

CASE REPORTS

Failures

CASE 1-F. M. A., a woman, thirty-four years old, had sustained a compound fracture of the left femur, twenty-six months before admission. An open reduction was done with a metal-plate fixation, non-union occurred. The plate was removed, with resultant infection. A suitable time after drainage had ceased (and about a year before admission), an autogenous onlay bone graft had been applied. This resulted in failure. On June 17, 1947, a dual graft was applied, fibular bone being used for massive grafts and tarsal bone for cancellous bone chips. The femur was dense and sclerotic at the fracture site. An attempt was made to preserve length by filling the gap between the bone ends with bone chips. In the early months after surgery, roentgenograms were encouraging, but absorption of the graft at the fracture site finally occurred. At a later operation, residual grafts were removed; by microscopic examination they were considered dead bone, in the nature of a sequestra.

This was an unfavorable case and the technique was faulty. It would have been better to have accepted shortening of the extremity.

CASE 2-F. D. S., a thirteen-year-old boy, fractured both bones of the right forearm. After several attempts at closed reduction had failed, an open reduction was done and the fragments were wired together. Non-union resulted. A homogenous rib graft was applied on May 20, 1947. The use of rib in this instance, without additional internal fixation, was an error in judgment. There was a good deal of tension on the graft at the fracture site; the screws pulled through the graft, and displacement of the fragment with subsequent non-union occurred. A second attempt at bone-grafting was made on February 24, 1948, with homogenous fibula from a fresh cadaver. A satisfactory graft was affixed to the radius, but absorption had taken place in the ulna and it was impossible to affix a suitable graft with screws. A dual graft was, therefore, applied, and was held in place with chromic catgut. The graft of the radius became sclerotic, but bone bridged across the fracture site and union took place. Union did not occur in the ulna.

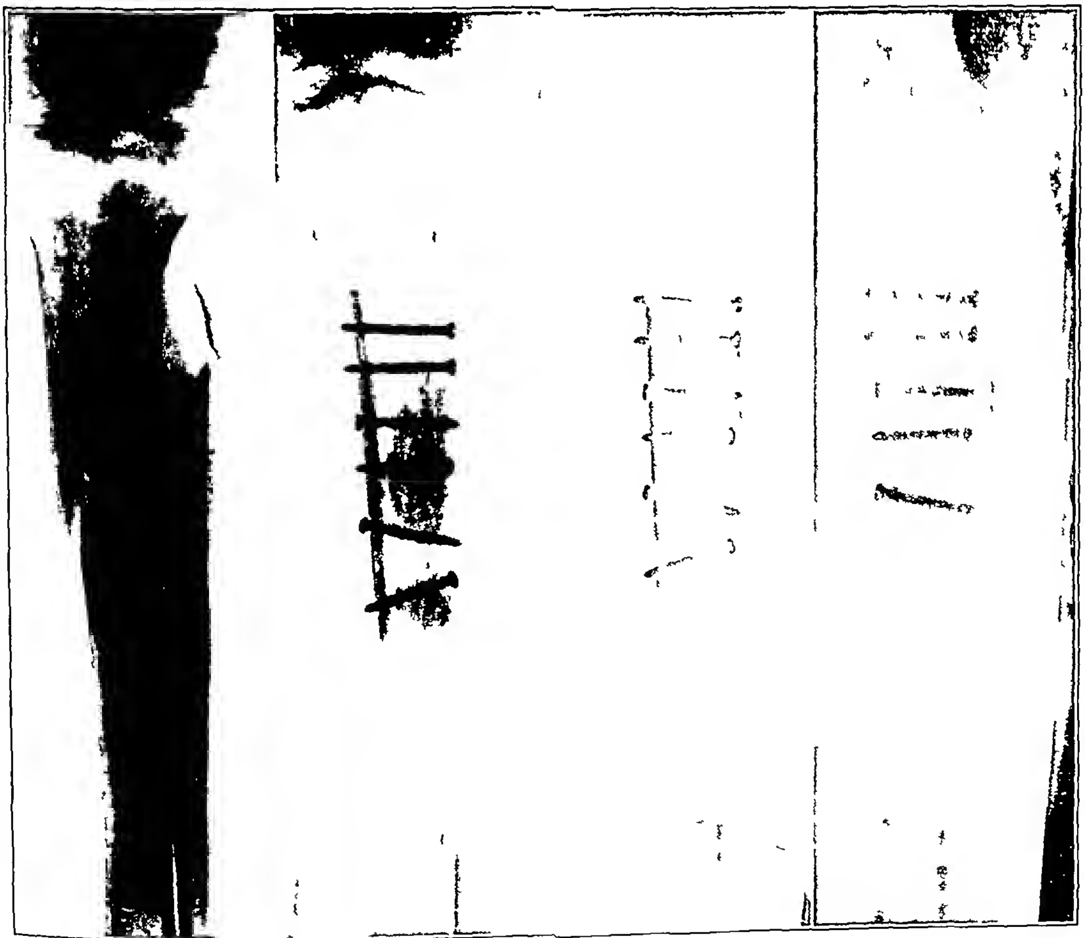

FIG. 2-A FIG. 2-B FIG. 2-C FIG. 2-D

Fig. 2-A. Case 5-F. Showing non-union of tibia.
Fig. 2-B. One week after application of dual graft.
Figs. 2-C and 2-D. Four months and seven months, respectively, after operation. Progressive destruction of the tibia from osteomyelitis may be noted.

CASE 3-F W B, a man, thirty-five years old, sustained compound fractures of the right tibia and fibula He was treated with Stader splints, non-union resulted After fourteen months a sliding bone graft was inserted, also resulting in failure He was admitted to the Medical Center, where, on May 13, 194[illegible], a homogenous bone graft was applied Dual massive grafts of the ulna were used, with chips from carpal bones to fill the space between the bone ends This patient's cast was changed two weeks after the operation at that time the wound was clean, the stitches were removed, and he was dismissed from the Hospital H[illegible] failed to report for after-care until several months later At that time he stated that, the week after leaving the Hospital or three weeks after the operation, he had removed his own cast, put on an old brace, started full weight-bearing, and gone to work as a filling-station attendant Of course, non-union resulted

A second operation was done on February 25, 1948 Dual onlay grafts of tibia from a fresh cadaver were used with cancellous bone chips from tarsal bones The patient's cooperation was somewhat better th[illegible] time After seven months, the cast was replaced by a brace, but weight-bearing was not permitted (Fig 1-A, 1-B, and 1-C) However, the patient began full weight-bearing without his brace A month later, while carrying a trunk up a flight of stairs, he stumbled and fractured his tibia through the site of the graft (Fig 1-D) A cast was applied, but he again failed to report for observation and it is understood that he entered a Veterans Hospital

Failure of the first attempt was due to lack of cooperation on the part of the patient, but the operation is listed as a failure The second attempt is considered a succe[illegible] Progressive union and filling in of the bone defect were taking place until destroyed by this patient's carelessness

CASE 4-F E D, a man, fifty fi[illegible] years old, suffered compound fractures of both tibiae on August 6, 1947 Immediate amputation of the left leg was necessary The wound of the right leg became grossly infected After a period of time, drainage ceased and the wound healed, although no union took place at the fracture site On June 3, 1948, a dual graft was applied and infection again ensued A small area of tissue loss appeared over the tibia, the infection seemed to be mild in character An attempt was made to cover the denuded area with a skin flap, but this was also a failure The grafts became sequestrated and there was obvious osteomyelitis of the tibia

FIG 3-A

Case 1-B Preoperative roentgenogram showing tuberculosis of the shoulder joint

FIG 3-B

FIG 3-C

One month and five months after surgery, there is clinical and roentgenographic evidence of fu[illegible]

CASE 5-F. R. F., a man, fifty-eight years old, suffered a simple fracture of the left tibia on October 5, 1947. Open reduction was done and the oblique fracture was fixed with two long screws. Non-union resulted (Fig. 2-A), but at no time following the open reduction did this patient show any evidence of infection. On February 26, 1948, a dual graft was applied, tibial bone from a fresh cadaver being used. After removal of the bone screw, a single drop of pus was exuded. A culture was taken, which was later reported as positive for *Staphylococcus aureus*. A mild infection followed, consisting chiefly of tissue loss over the tibia. An attempt was made to cover the area with skin flaps, but this was unsuccessful. Sequestration of the graft and osteomyelitis were the result (Figs. 2-C and 2-D).

FIG. 4

Ten months after surgical fusion of a shoulder. Metatarsal bone was used as the bone peg.

CASE 6-F. A. S., a seventeen-year-old girl, had had a large cyst removed from the mandible; osteomyelitis ensued. Three bone grafts had been done, prior to admission. On May 6, 1948, a rib was used in an attempt to fashion an alveolar ridge, so that a prosthesis might be fitted. This graft was absorbed, although no infection was present.

This was a most unfavorable case, as little bone remained in which to fasten a graft.

CASE 7-F. J. K., an eighteen-year-old boy, was admitted with a malunited fracture of the tibia. An osteotomy was done on May 20, 1948, for correction of the deformity. A metal bone plate was applied to hold the tibia in correct position, and a rib was slipped beneath the periosteum, on the posterior surface. The postoperative course was uneventful. At eight weeks, when the cast was changed, ulceration was found in the wound over the tibia. There was mild drainage for several weeks, and the skin healed. Roentgenograms showed bone loss in the rib graft, which was evidently the site of infection. Non-union resulted.

CASE 8-F. W. P., a ten-year-old boy, had an adduction deformity of the thumb, due to cerebral palsy. A Thompson bone-block operation was done on May 20, 1948, a metacarpal bone being used between the first and second metacarpals. One end of the graft was absorbed, and displacement followed. There was no infection.

It is believed that faulty technique was largely responsible for this failure.

Selected Successful Cases

CASE 1-S. C. K., a negro man, twenty-eight years old, had arrested pulmonary tuberculosis, and active tuberculosis of one kidney and the left shoulder. First a nephrectomy was done and then, on April 20, 1948, an arthrodesis of the right shoulder. The shoulder condition had been rapidly progressive and, at the time of operation, there was a large abscess of the shoulder with a draining sinus low on the brachium (Fig. 3-A). After the joint had been opened, it was found that the head of the humerus, very necrotic, was floating in about 180 cubic centimeters of pus, contained in a markedly enlarged capsule. The head of the humerus was debrided as well as possible, the glenoid cavity was freshened, and all soft tissue was removed from the subacromial area. The inferior surface of the acromion was denuded to bleeding bone. The head of the humerus was pushed firmly against the glenoid and acromion process and the arm was held in the desired position, while a drill hole was placed through the acromion process and into the head. This was enlarged to accommodate a rib, which was then driven through the acromion process, into the head. Bone chips, fashioned from ribs, were placed in the dead space between the head of the humerus and the scapula. Five months after the operation, there was clinical fusion and no drainage. Roentgenograms (Fig. 3-C) showed excellent amalgamation of the component bone elements.

This technique has been used in two other shoulder operations with satisfactory results. Figure 4 shows one of them, ten months after operation.

CASE 2-S. V. B., a woman, thirty-nine years old, had arrested pulmonary tuberculosis and active tuberculosis of the left hip (Fig. 5-A). An arthrodesis of the hip was done on March 2, 1948. The greater trochanter was turned back and the superior margin of the acetabulum was turned up to form bone flaps. The superior surface of the neck of the femur was freshened. An iliac graft from a fresh cadaver was laid on

Fig 5-A Fig 5-B Fig 5-C Fig 5-D

Fig. 5-A. Case 2 S. Preoperative view shows tuberculosis of the left hip.
Fig. 5-B. Two months after surgical fusion.

Roentgenograms taken four months and six months after operation show progressive fusion to completion.

FIG 6-A

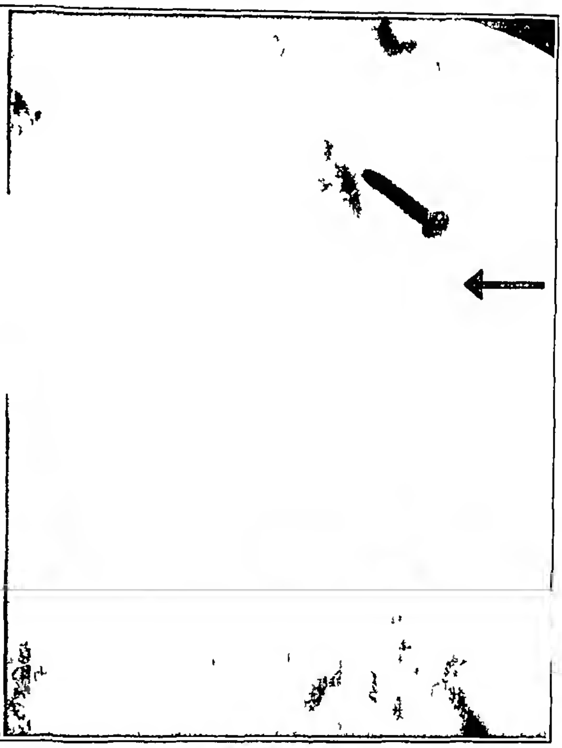

FIG 6-B

Fig 6-A Case 3-S Showing massive graft of the lumbar spine two and one-half months after operation

Fig 6-B A fracture of the graft, just below spinous process to which the screw is affixed, occurred three and one-half months following surgery

FIG 6-C

FIG 6-D

Fig 6-C Five and one-half months after surgery and two months following the fracture, a good cloak of callus surrounds the fracture site

Fig 6-D At eighteen months, there is marked hypertrophy of the graft

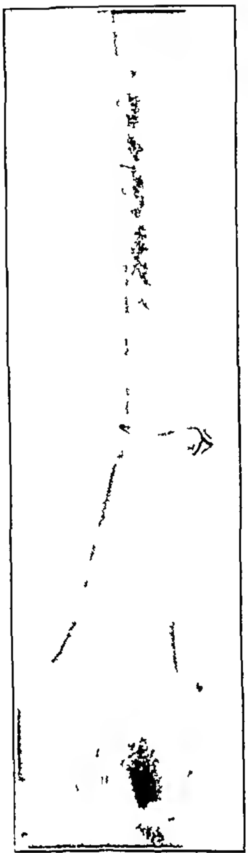

Fig 7-A

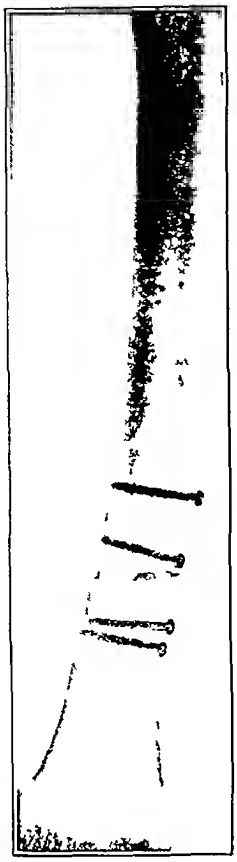

Fig 7-B

Fig 7-C

Fig 7-A Case 4-S Show ununited fracture of the femu at time of admission

Figs 7-B and 7-C six months and fourteen month after dual grafts had been a plied Solid union has occurr both clinically and by roen genographic examination

Fig 7-D Ununited fracture of tibia at time of admission

Figs 7-E, 7-F, and 7-G Two, four, and fourteen month after application of ma ne onlay grafts, roentgenogram show progressive union Weight-bearing has not yet been permitted

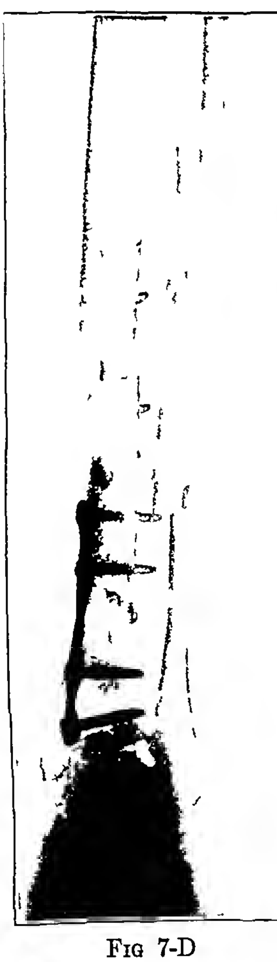

Fig 7-D

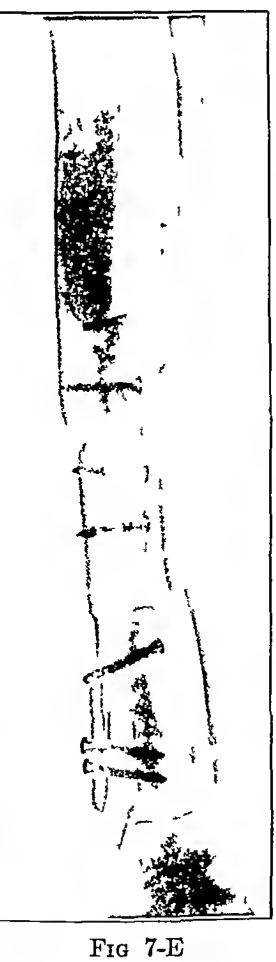

Fig 7-E

Fig 7-F

Fig 7-G

Fig 8-A

Fig 8-A Case 5-S Non-union of fracture of tibia at the time of admission

Figs 8-B, 8-C, and 8-D Roentgenograms, taken at four, eight, and ten months after surgery, show progressive healing to complete union

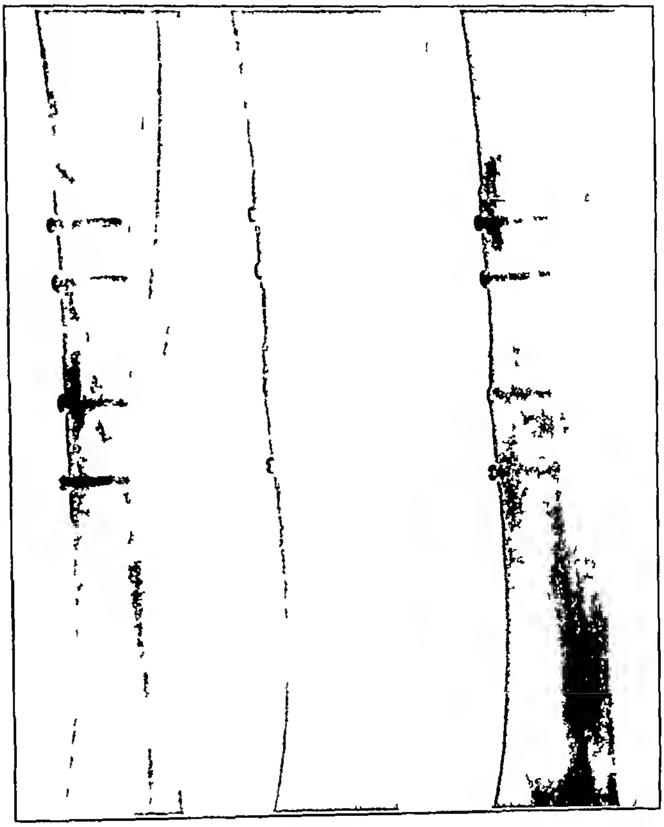

Fig 8-B Fig 8-C Fig 8-D

the neck of the femur, under the bone flaps, and was held in place by a screw through the greater trochanter and graft (Fig 5-B) There were no postoperative complications, and excellent fusion followed (Figs 5-C and 5-D)

Case 3-S In G P, a man of twenty-five years, a spine fusion was done on December 31, 1945, for paralytic scoliosis The spinous processes of the lumbar vertebrae were denuded to raw bone on one side and a gutter was made in the laminae at their base A long piece of split fibula fitted nicely into this bed and was easily held by a single screw, passed through the graft and a spinous process Three months after operation, fusion appeared satisfactory and the patient became ambulatory, wearing a spine brace (Fig 6-A) At three and one-half months, the patient was wrestling with a nephew and fractured the graft (Fig 6-B) Six weeks later, roentgenograms showed callus about the fracture site, and the fractured graft progressed to complete union (Figs 6-C and 6-D)

On December 30, 1947, the lower portion of the spine was fused Ribs were used as grafts in this instance, placed between split spinous processes and in a gutter at one side During the course of the operation, a portion of the fibular graft was removed, the pathologist's diagnosis was normal bone Satisfactory fusion was obtained in both instances, and marked hypertrophy of the first graft had occurred

Case 4-S H T, a man, forty-two years old, sustained a simple fracture of the lower third of the left femur, and two fractures of the left tibia, one at the junction of the upper and middle thirds, and the other in the lower third All three fractures were treated by open reduction The femur was wired (Fig 7-A), and plates were placed on the fractures of the tibia The sites of the tibial fractures became infected When this patient was first seen, eleven months after the accident, there was non-union of all three fractures and draining sinuses over the lower portion of the tibia A dual graft of femur from a fresh cadaver was placed on the fractured femur and, at the same time, the plates were removed from the tibia The surgical wound of the femur healed promptly, and soon thereafter the incisions over the tibia healed Two months later, massive tibial grafts from a fresh cadaver were placed over the fracture sites in the tibia Cancellous bone chips (femoral condyles from a fresh cadaver) were packed about these At the time of operation, there had been little hope of union, as the central portion of the patient's tibia was practically a sequestrum, and the lower end of the tibia was so atrophic that a hemostat could easily be pushed through the bone Union of the femur occurred, both clinically and by roentgenographic examination (Figs 7-B and 7-C) Clinically, the fracture sites in the tibia felt firm, and roentgenograms over a fourteen-month period showed progressive union (Figs 7-E, 7-F, and 7-G)

The bone bank filled a real need in this case of multiple non-union

FIG. 9-A

Case 6-S. Lateral and anteroposterior views of osteomyelitic tibia at the time of admission.

CASE 5-S. R. H., an eighteen-year-old boy, fractured his left tibia and fibula on May 5, 194, resulting in non-union (Fig. 8-A). On April 27, 194, an onlay bone graft was applied, the femur from a cadaver being used. An excellent result was obtained (Figs. 8-B, 8-C, and 8-D).

CASE 6-S. C. S., a male, twenty-one years old, contracted hematogenous osteomyelitis of the tibia about four years before admission. He had had four operations with no relief. When first seen, he had a large fungating mass over the lower anterior portion of the tibia, with considerable drainage (Fig. 9-A). On September 3, 1946, the fungating mass was excised and all necrotic bone was curetted from the tibia. Posterolateral, longitudinal skin incisions were made, the skin was pulled together over the tibial defect and sutured. The wound healed promptly and no further drainage occurred (Fig. 9-B). On October 22, 1946, an incision was made through good skin, and the tibia was exposed at the site of the defect. A large tibial onlay graft was placed over the open side of the cavity, which was packed with cancellous chips from tarsal bones.

Follow-up roentgenograms showed progressive union (Figs. 9-C and 9-D). For over eighteen months, this patient has walked without apparatus and has been doing heavy farm work (Figs. 9-E and 9-F).

NOTE: In Cases 4-F and 7-F, reported as failures, union has occurred since this paper was presented.

DISCUSSION

From the experiences reported here, it seems obvious that homogenous bone, preserved by freezing, has not only limitations but also dangers. When used in the form of chip grafts in arthrodesing operations or in certain types of bone defects, excellent results may be expected. However, massive grafts are not so successful in cases of non-union. The same statements are applicable to autogenous grafts.

As regards amalgamation with recipient bone, there is certainly no reason to assume that the homogenous graft has inherent qualities which would make it superior. It may be just as good as autogenous bone, but not better. The only way in which the homogenous graft might lend itself to better results is that the surgeon may have as much bone of a particular type as he may desire. The results in this series, as they concern massive homogenous grafts for the repair of non-union of fractures, are not so good as the author's experience with autogenous grafts. However, the cases in this report have been, for the most part, difficult ones, and in several instances the homogenous graft has been called upon to do more than one would expect of an autogenous graft. It is felt that there is a greater tendency for the massive homogenous graft to "die" and, on the whole, the time of amalgamation has been longer.

This last statement is an impression, without definite data to prove it. In some cases, however, massive homogenous grafts have amalgamated as promptly as would be expected of an autogenous graft.

Many other factors are involved in the success or failure of any bone-graft procedure. The mechanics of the operation are most important and, in several instances of failure in this series, undoubtedly played an important part. In addition, there must be considered the condition of the recipient bone, the general condition of the patient, the cooperation of the patient, and many related factors.

It is fallacy to assume that the danger of infection is less with homogenous bone that

Fig 9-B

Fig 9-C

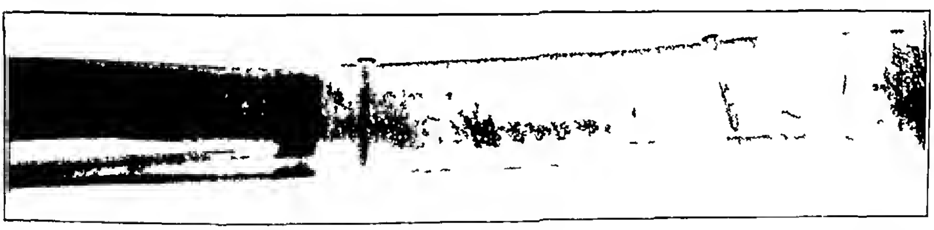

Fig 9-D

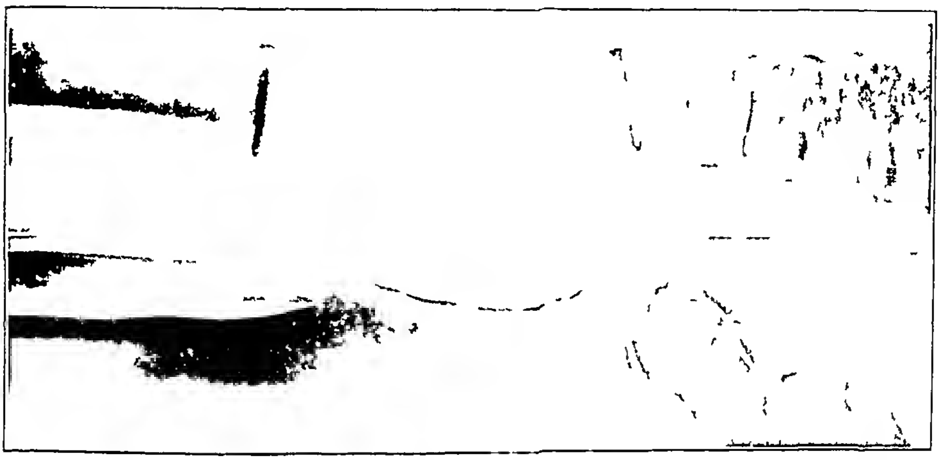

Fig 9-E

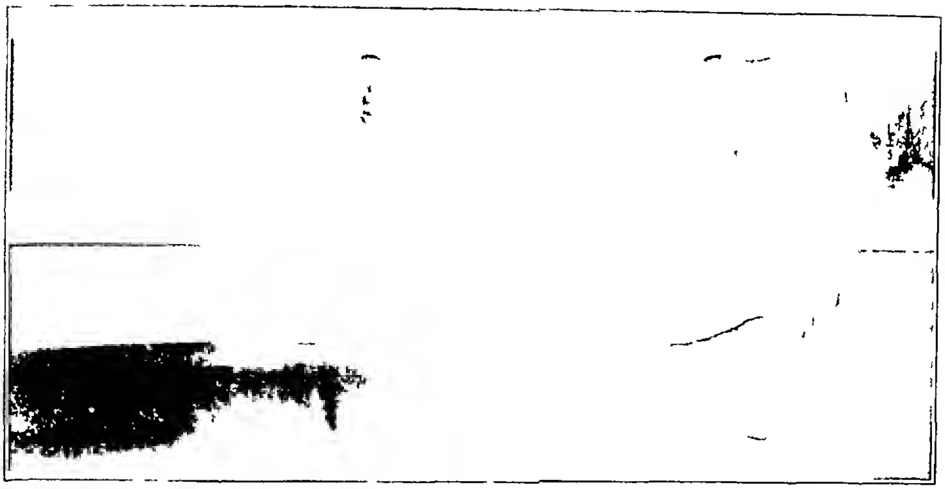

Fig 9-F

Fig 9-B After removal of affected bone

Figs 9-C and 9-D One and one-half and four months after application of graft

Lateral and anteroposterior roentgenograms taken eleven months and two years, respectively, after bone-grafting

with autogenous Homogenous bone must be handled more than the autogenous bone, thus creating a greater hazard However, this danger is offset by the fact that the patient does not have to undergo a second incision for the removal of bone, with its attendant possibilities of infection and fracture This series presents a high percentage of infection, but in only one instance did infection occur in a truly clean field (Case 7-F) Roentgenograms of this case indicate that the rib graft was the seat of the infection Another rib from the same donor was used in Case 6-F It became absorbed rapidly, but there was no drainage In all other cases where infection ensued, there was infection of the site, either past or present, and it would be difficult and unfair to place the blame entirely on the graft material No attempt was made to sterilize the bone-graft material in this series Such procedures are now under trial, and they may prove of value

It is felt that bone from fresh cadavera is just as efficient as that taken from patients Since it is generally believed that iliac bone is more efficient as regards osteogenetic properties, and since the cadaver offers an ample supply, the author has in recent months used iliac bone from fresh cadavera almost to the exclusion of other types

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CLINICAL EVALUATION OF THE MERTHIOLATE BONE BANK

A Preliminary Report *

BY FRED C REYNOLDS, M D, AND DAVID R OLIVER, M D, ST LOUIS, MISSOURI

From the Department of Surgery, Washington University School of Medicine, St Louis

To justify the use of homogenous bone grafts, a clear understanding of the fate of transplanted bone, both autogenous and homogenous, is necessary The consensus is that autogenous bone grafts are superior to homogenous grafts, because of the supposition that some elements of the transplants survive and retain their osteogenetic properties [1,3,8,10,14] However, there are those who maintain that all elements of a bone transplant die and are replaced by the host tissue, regardless of the source of bone [2,11,16] If the claims of the latter group are correct, there should be but minor differences in the process of fixation and replacement of autogenous and homogenous bone grafts

In the past year, the authors [16] have made an experimental comparison of the fate of autogenous and homogenous bone grafts in dogs The observations are in complete agree-

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 26, 1949

ment with those of Barth, in that no evidence was found that any elements of autogenous bone transplants live and have reproductive powers.

The process of fixation and replacement of both autogenous and known dead homogenous bone is identical. It is accomplished by appositional new-bone growth from the host tissues in both instances. However, the early phases of healing occur at a slightly more rapid rate with the autogenous than with the homogenous grafts. The exact significance of the observation is unknown to us, but the explanation is probably related to the unknown factors of tissue specificity and host reaction, rather than to any persistence of life in the autogenous grafts.

The transplantation of homogenous bone is not a new procedure. Its use in the fresh state was first reported by Macewen in 1880, and by many workers thereafter. More recently, attempts have been made to preserve bone in various states as reported by Orell. Several French surgeons are said to have used frozen preserved bone[6]. Inclán, in 1942, demonstrated the successful use of frozen autogenous and homogenous bone. Bush has popularized the use of frozen homogenous bone as a "bone bank".

Morgan, Jamieson, and Powell reported the use of merthiolate solution as a preservative for biological products. O'Connor, in 1939, and Brown and DeMere have described the successful use of cartilage preserved in merthiolate. The simplicity and safety of this method of preservation of tissue aroused the authors' interest in the possibility of its application to the preservation of bone. Therefore, experimental studies were made, comparing the process of healing of merthiolate-preserved homogenous grafts with frozen and boiled homogenous grafts, as well as with autogenous grafts. From these studies, the authors concluded that the fixation and replacement of the merthiolate-preserved homogenous bone was essentially the same as that of the fresh autogenous grafts. Experimentally, bone preserved by freezing or by aqueous merthiolate was indistinguishable. Boiled homogenous grafts healed by the same process, but the healing was definitely delayed. From these experiments the clinical use of merthiolate-preserved bone seemed justifiable.

The procedure adopted for the establishment of a "merthiolate bone bank" is as follows. The bone is obtained from three sources: (1) ribs removed under aseptic conditions at thoracotomies and thoracoplasties, (2) bones obtained from amputations of uninfected parts, and (3) cancellous and cortical bone obtained at selected autopsies under as sterile conditions as possible. In preparing for storage the bone removed from these sources, sterile equipment and operating-room technique are employed. The periosteum and attached soft tissues are carefully removed from the bone, which is then split and cut into convenient lengths. A culture of the marrow contents is taken.

The bone is then put into sterile jars, containing a 1 to 1,000 solution of clear aqueous merthiolate. It is important that all bone be completely covered by the solution. At the end of two weeks, the bone is removed under operating-room technique, all remaining soft tissues are cleaned off, and it is placed in sterile jars containing a 1 to 5,000 solution of aqueous merthiolate. Another culture is taken at that time. The bone is kept in the 1 to 5,000 solution thereafter, being changed at two-week intervals and cultures being made. No grafts are removed from the bank for clinical use until at least two negative cultures have been obtained. To date, the authors have not encountered a single positive culture.

The container of preserved bone can be kept either in the operating room at room temperature or in a nearby household refrigerator. When a graft is needed, the container is opened in the operating room and the desired piece of bone is removed by the surgeon with sterile forceps. After being rinsed in normal saline solution, the graft is ready for use.

At the present time, merthiolate-preserved homogenous bone has been used in seventy-one patients. This report, however, presents the findings in the first forty-two consecutive cases in which merthiolate-preserved homogenous bone was used. The types of operative procedures and the general results obtained from each are shown in Table I.

TABLE I

RESULTS IN FORTY-TWO PATIENTS

Operation	No of Patients	No of Failures
Arthrodesis of major joints	5	0
Non-union	9	3
Spine fusion	15	2
Obliteration of osteomyelitic cavities	5	2
Obliteration of tumor cavities	3	0
Osteotomy defects	2	0
Open reductions	2	0
Aseptic necrosis of femoral head	1	0
Totals	42	7

Of nine operations on patients with non-union, three are considered failures at this time Two of these failures occurred in fractures of the ulnar shaft, the other involved an old compound fracture of the lower portion of the humerus Ribs were used as grafts in each instance This type of graft does not lend itself to firm internal fixation, and is generally considered to be inferior to compact cortical bone for use in these locations It may be that this factor has contributed to these failures However, in two other cases of non-union of the ulnar shaft, treated in an identical manner, satisfactory union occurred One of the patients with failure of union after an ulnar fracture had a recurrence of infection following the grafting procedure, which necessitated sequestrectomy at a later date Figures 1-A 1-B, and 2 illustrate the results obtained in cases of non-union

Bank bone was used to obliterate the defects remaining after saucerization for osteomyelitis in five patients, each of whom had a draining sinus One of these sites healed *per primam* and has remained healed, in four, drainage continued after operation The drainage in two of them, however, subsided promptly without further surgery, the sinuses have remained healed and the patients have been free of symptoms The other two patients, whose operations must be considered failures, require some explanation

A I, a doctor, had had osteomyelitis of the upper portion of the tibia with extensive bone defects and soft-tissue defects for nine years Saucerization, grafting with bank bone, and the swinging of a large pedicle flap were performed in one stage This over-ambitious surgery resulted in failure, with infection and necrosis of the skin flap

K B had had non-union of the upper portion of the femur with infection for eight years Three previous attempts at autogenous bone-grafting, performed elsewhere, had failed A large osteomyelitic defect was present, together with extensive soft-tissue scarring Following sequestrectomy and bridging of the defect by rib grafts, the wound was closed However, the infection persisted, and drainage and non union were present when the patient was last examined

Figures 3-A, 3-B, 4-A, and 4-B show successful results obtained in patients of this group

Spine fusions in this series were of the modified Hibbs type, reinforced by large amounts of merthiolate-preserved bone Of the fifteen patients in this group, ten had fusions which appear to be definitely solid In two patients, the final result is not yet known, one died before the graft was solid A pseudarthrosis developed in one patient and refusion was required This we believe to have been caused by a fracture of the graft as it followed an injury in which the patient heard a sharp snap, accompanied by pain At operation, all the bone was solid, except at the line of pseudarthrosis The other patient has only recently presented evidence of pseudarthrosis, reoperation has not yet been done

Arthrodesis of major joints, including the hip, knee, ankle, wrist, and subtalar joints was performed successfully in five patients Intra-articular fusion, reinforced with bank bone, was done in all instances No failures were encountered in this group

Fig. 1-A

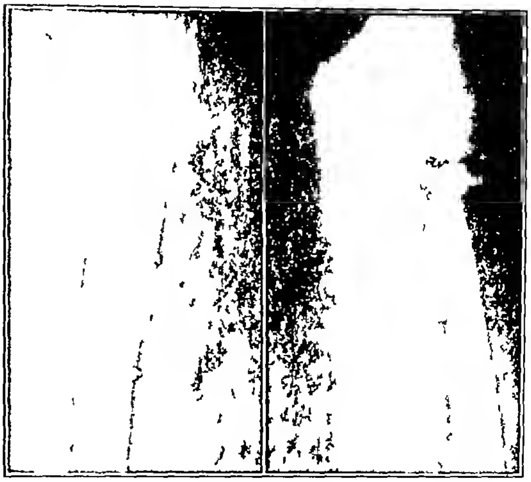

Fig. 1-B

C. F., a white male, aged forty-four, had non-union of the shaft of the ulna, following a Monteggia fracture five months previously. An attempt at internal fixation had been made elsewhere.

Fig. 1-A: Roentgenograms taken at the time of admission.

Fig. 1-B: Appearance nine months after resection of head of radius and dual onlay graft. Ribs from the merthiolate bone bank were used for grafting. Excellent function was regained.

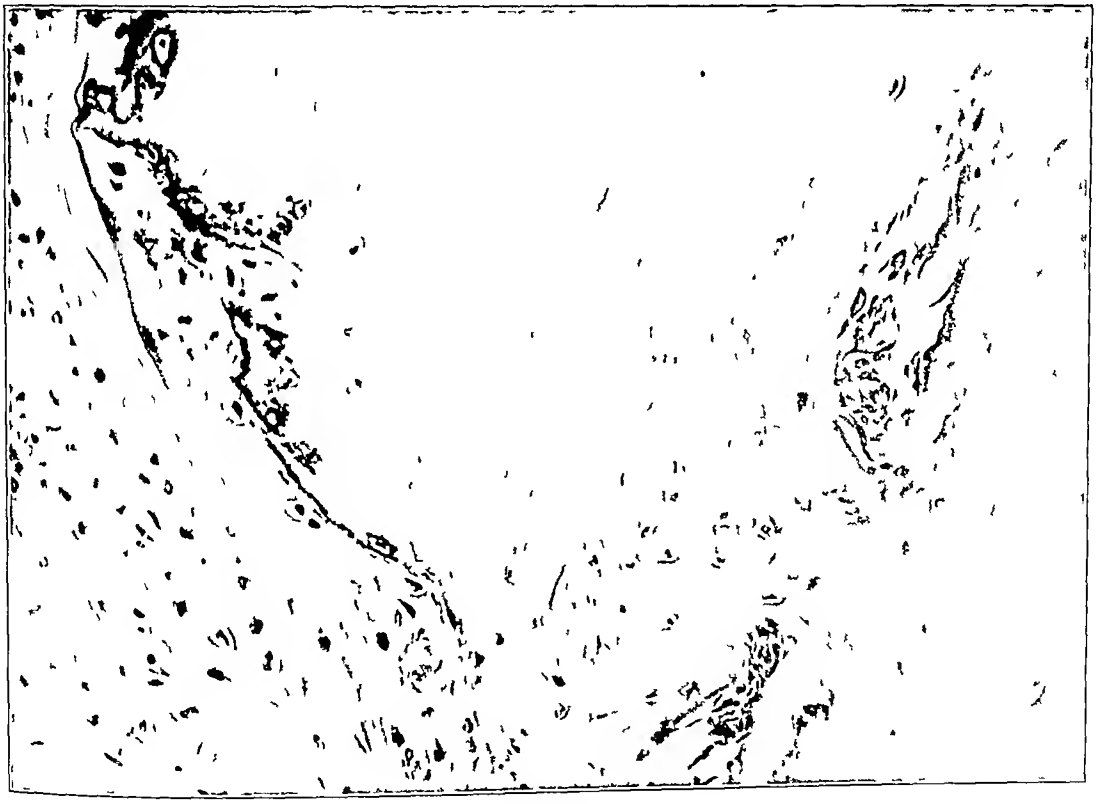

Fig. 2

J. K., a white male, aged forty-eight, had non-union of the shaft of the femur of eleven months' duration. The original treatment was open reduction and plate fixation. At the time of admission, the plate had broken and there was non-union. Two plates and merthiolate rib grafts were then applied. Four months after the second operation, definite union was evident grossly.

The process of replacement of the merthiolate graft by appositional growth of the host bone was identical, microscopically, to that seen in experimental animals.

In the remaining cases (Table I), the wounds healed by first intention, and all grafts appear to be fusing in a satisfactory manner. Bank bone was employed to obliterate the defect in three instances of benign bone tumor. In each case the postoperative course was uneventful and the grafts healed satisfactorily (Figs. 5-A and 5-B).

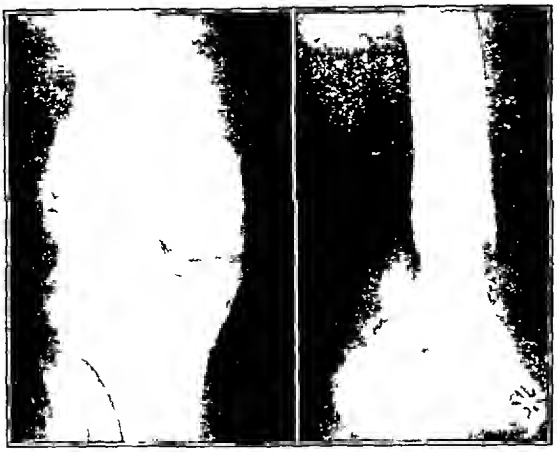

Fig 3-A

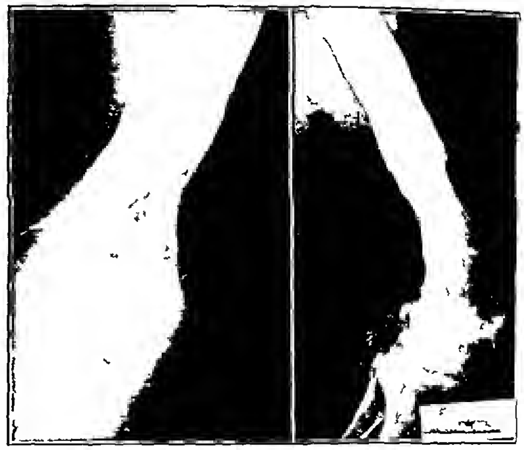

Fig 3-B

G A, a white male, thirty-eight years old, had chronic osteomyelitis of the left femur of twenty-three years' duration Copious drainage was seen at the time of admission A saucerization and sequestrectomy were done

Fig 3-A *After two weeks, the defect was filled with merthiolate rib grafts and the wound was closed* These roentgenograms show the femur after saucerization and before grafting

Fig 3-B Roentgenographic appearance twelve months after operation The patient has had no drainage since one month after operation and has been symptom-free

Fig 4-A

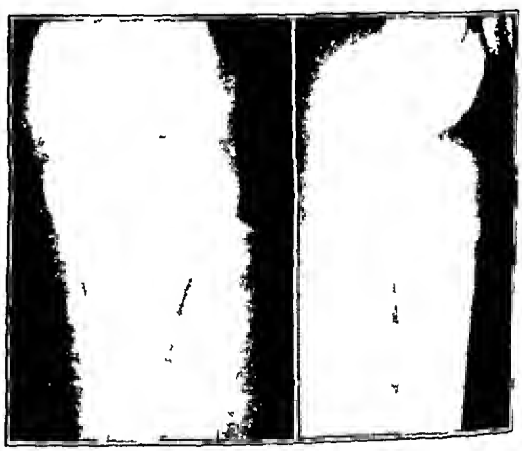

Fig 4-B

M B, a white girl, aged twelve, had chronic osteomyelitis of the proximal portion of the right tibia of six months' duration The focus was draining at the time of admission

Fig 4-A Preoperative roentgenograms Saucerization, sequestrectomy, filling of the defect with merthiolate rib grafts, and wound closure were done in one stage The wound closed *per primam*, and the patient has had no drainage or symptoms since operation

Fig 4-B Roentgenograms taken three months after operation

Osteotomy defects were filled in two patients and solid union resulted It seemed advisable to employ a bone graft as an aid in internal fixation in two instances One was a subcapital fracture of the hip, in which grafting augmented a Smith-Petersen nail In the other case, a merthiolate bone graft was used to fill a defect in the calcaneus, which had remained after elevation of a depressed fracture

CONCLUSIONS

1 The process of fixation and replacement of both autogenous and known dead homogenous bone grafts is accomplished in an identical manner, experimentally and clinically

2 The merthiolate bone bank offers a simple, inexpensive, and aseptic method of preserving homogenous bone

3 Merthiolate-preserved bone is well tolerated in the tissues, and early results obtained with grafts from the merthiolate bone bank compare favorably with autogenous grafts under similar circumstances

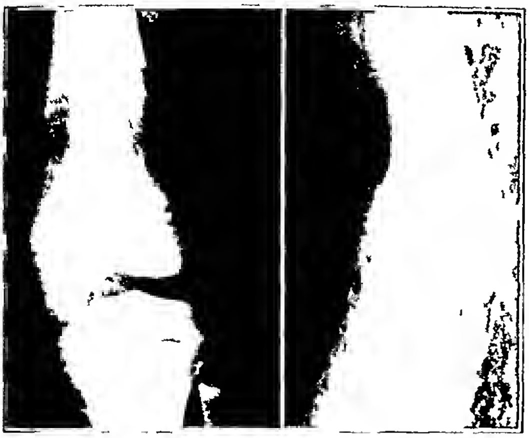

Fig. 5-A

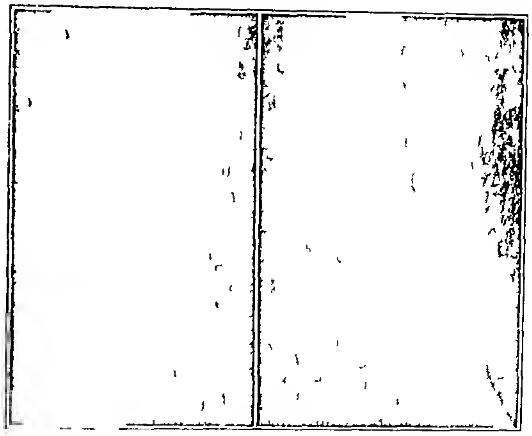

Fig. 5-B

D. B., a white male, aged fourteen, had a central chondroma of the distal portion of the femur of eight months' duration, causing partial epiphyseal growth arrest on the lateral aspect.
Fig. 5-A: Roentgenograms taken at the time of admission. The tumor was excised locally and the defect was filled with merthiolate ribs and iliac-bone chips.
Fig. 5-B: Appearance of defect two months after operation.

4. No sensitivity to merthiolate has been encountered in any case.

5. Experimentally and clinically, the early phases of healing are somewhat slower with homogenous grafts than with autogenous grafts. Therefore, it is important that immobilization be continued over a longer period of time.

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DISCUSSION

Dr. Alberto Inclán, Havana, Cuba: It is a great privilege for me to open the discussion on the interesting papers just presented by Dr. Reynolds and Dr. Oliver, and by Dr. Weaver. This privilege is probably due to my previous work in the use of preserved bone for grafting purposes.

Up to a year ago, when we were able to obtain a deep freezer and organize a bone bank, we kept our bone in citrated blood at a temperature of 2 degrees centigrade in a domestic refrigerator. It is gratifying to know that bone banks are being developed in many hospitals.

I have no personal experience with the use of antiseptics and bacteriostatic solutions as preserving agents for homogenous bone. The technique used by Dr. Reynolds and Dr. Oliver is similar to that published by Brown and DeMere for a cartilage bank.

The authors' recommendation of their method of bone preservation is based upon their belief that all transplanted bone is dead bone. We do not entirely agree with this statement. More knowledge is necessary to decide this controversial point. Fresh transplanted bone seems to be rapidly revascularized before its cells have suffered necrosis. Histological examination of bone kept under refrigeration has demonstrated the preservation, for a certain period of time, of the characteristics of normal bone cells, which may mean that this tissue is capable of life if revascularization can be obtained within the proper time. The condition of the recipient bone must be considered of the utmost importance.

The recent experimental work of Kiehn, Friedell, and MacIntyre, of Western Reserve University ("Study of the Vitality of Tissue Transplants by Means of Radioactive Phosphorus", Plastic and Reconstruct. Surg., 3: 335–339, 1948) should be emphasized, since they concluded that fresh cancellous bone exists "as a vital graft, forming its own blood supply and integrating itself as a vital part of the system from the time it is transplanted. This is shown by the immediate assimilation of P^{32} by the vital grafts, as compared to low uptake by the devital transplants" (boiled bone). Kiehn and his associates also observed that "refrigeration may not depress the recovery of transplanted bone beyond a short initial stage".

More time will be necessary to evaluate the use of this new method of bone preservation. Changing the solutions every two weeks with frequent manipulation, as well as the possibility of the recipient's intolerance to mercurials, must be considered as possible disadvantages.

Dr. Weaver presents a very thorough study of the evolution of preserved homogenous bone. It is difficult to evaluate his results, due to the different types of operations performed and the various grafting materials utilized.

Use of a bone graft in an infected recipient bone will naturally increase the percentage of infection. I wouldn't consider the rather high incidence of infection reported by Dr. Weaver as meaning a greatly increased danger of infection with the use of preserved bone, although he has not done bacteriological tests. In his series, infection developed in only one case which had previously been clean.

I agree with Dr. Weaver's statement that many factors in the postoperative evolution of bone grafting are of importance in the production of failure. To those he has mentioned must be added an inaccurate fitting of the graft in the treatment of non-union of fractures. When using inlay grafts, I adhere to the principles recommended by the late Fred H. Albee. In many cases we add a dual graft, one of cancellous bone, as the best solution for some ununited fractures.

We lost one graft in our last thirty cases, using homogenous bone from the deep freezer. The patient, with a tuberculous hip ready for a Brittain extra-articular fusion, had a deep tuberculous abscess. Still, the implantation of the graft was carried out and suppuration and disintegration of the graft was the result. The preserved bone graft must not be blamed for this failure, but rather poor judgment in its use.

I have always expressed the opinion that a preserved bone graft should be used only when fresh autogenous bone is not available. However, during my experience with the use of preserved bone grafts, I have found that they can be substituted for fresh autogenous bone transplants. In some of my cases the grafts have been placed in the worst conditions for their integration and growth, still they have acted as well as fresh transplants.

Dr. Philip D. Wilson, M.D., New York, N. Y.: I think we are all in agreement that preserved homogenous bone grafts can be used with great advantage in orthopaedic operations. The question that is raised in the paper by Dr. Reynolds and Dr. Oliver is how the bone can best be preserved. They propose immersing it in a chemical solution—namely, merthiolate—in order to prevent bacterial invasion and putrefaction; they claim that this does not affect the osteogenetic properties of the bone, or its toleration in the host tissue. They have experimented with the use of this bone in animals and have a fine exhibit in the scientific-exhibition section of this meeting, which attempts to show what happens.

I have been working with preserved bone grafts since 1946 and, like Drs. Weaver, Bush and Garber, and many others, have been using refrigeration in sterile jars, at a temperature of between 10 and 20 degrees below zero centigrade, as the method of preservation. By careful bacteriological control of the material, we have been able to prevent infection. In a series of more than 200 operations in which this bone was used, our loss of bone grafts has been under 2 per cent., which is about the same as when fresh autogenous grafts are used.

My criticism of the merthiolate method of preservation is that, when the bone is immersed in a chemical solution, there is the risk of altering the nature of that bone, because the chemicals are not inert. Even though the solutions are diluted, a foreign, toxic substance has been added which, in spite of attempts to wash it out, remains in the tissue, as is shown by the persistent stain. I believe that this foreign chemical is an

irritant and that it throws a greater burden on the healing powers of the host tissues than is produced when refrigerated bone is used.

The series of cases reported is too small to give a true picture of what happens, but even so, the authors mentioned one case with loss of the graft and another with a draining sinus, although they reported *no* infections.

Furthermore, the use of a chemical solution definitely destroys vitality in the bone. I am not yet convinced that there is complete absence of life in refrigerated bone, even though the histological studies of the healing grafts show very little evidence of it. The same may be said of the studies of healing of fresh autogenous grafts. There is a great deal of evidence to prove that living cells can resist prolonged exposure at very low temperatures,—as, for example, bacteria, leukocytes, and tumor cells. I like to feel, when bone-grafting, that the cells have been given the chance to play a part in the healing.

It seems to me, in this discussion of methods of preservation of bone, that there is great similarity to the early arguments over Lister's antiseptic method as opposed to the aseptic method in operative surgery. I prefer to obtain sterile grafts and to keep them free from contamination, while the authors prefer the antiseptic method. It was a preference for Halsted's technique of using heat-sterilized silk for ligatures and sutures that led many of us to give up the use of chemically sterilized catgut, and we believe that the wounds heal with less reaction, because of the absence of irritation.

The merthiolate method offers only one advantage, in my opinion, over sterile refrigeration,—that is, that it may protect against the transmission of malaria or the virus of hepatitis or syphilis. Such a complication is, however, very rare, and need not be feared when proper precautions are taken. We have had two instances of hepatitis and one of malaria after operations in which refrigerated homogenous bone grafts had been used, but all of these patients had received blood transfusions, and our studies indicated that the blood conveyed the infection and not the bone.

I hope that Dr. Reynolds and Dr. Oliver will continue their work and will give us a later report of results when their series is larger. There is room for many different techniques in surgery, but we would be wise not to avail ourselves of new methods until after they have been thoroughly tried and proved. For this reason I shall continue to employ the method of refrigeration of sterile bone grafts, in preference to the merthiolate method.

I consider Dr. Weaver's paper interesting and worth while. He has done two things that have not previously been reported. First, he has used cadaver bone, and, second, he has shipped refrigerated bone by the dry-ice method to other cities for use by other surgeons. Cadaver bone is difficult to obtain because of legal restrictions. Even when a person wills his body for scientific purposes, it is not permissible to make use of it unless the consent of the next of kin has first been obtained. The law provides that, after death, legal title to the body is vested in the nearest relative. Even when no relative appears to claim the body, it must be kept for a certain period before it can be disposed of. Infection and decomposition set in rapidly, and the safe period in which to obtain the bone is only about six hours. In addition, the bone must be obtained under aseptic conditions similar to those in an operating room, which practically limits the availability of cadaver bone to a death occurring in the hospital. Also, the death must have occurred from some cause other than infection or tumor. All of these limitations have prevented us from using cadaver bone, and Dr. Weaver is to be congratulated upon solving these problems. Our own stock has been maintained by donations from patients undergoing operations where bone must be excised, and from amputated limbs. Resected ribs from operations upon the chest are also a valuable source of material for the bone bank.

I think Dr. Weaver is perhaps a little discouraged, and unnecessarily so, over his failures. The number of infections was larger than is desirable, but this was largely because he was pioneering and had not developed an adequate method of storing and sealing his bone material against infection. Also, he did not employ careful bacteriological control. I am sure that his results will improve, now that his bone bank is better organized and checked.

Finally, I would like to say a word about the healing properties of refrigerated bone or preserved bone in comparison with fresh autogenous bone. No one can say at the present time that preserved bone serves in all respects equally as well as fresh autogenous bone. It certainly serves well for packing bone cavities in which healing is going on, and I think the results are comparable. Whether it serves as well for cancellous or cortical grafts, we cannot as yet answer. Much more remains to be learned, and it will require many years of experience before we can determine its exact field of usefulness. That preserved bone has a field of usefulness is the only thing I would dare to be dogmatic about at present.

I wish to thank the speakers for their valuable presentations, and to express my pleasure at the privilege of having been invited to discuss them.

Dr. Fred C. Reynolds (closing): Concerning Dr. Inclán's discussion, the report of Kiehn, Friedell, and MacIntyre in regard to the assimilation of P^{32} does not necessarily demonstrate that fresh cancellous bone exists as a vital graft. In all probability, this only indicates the speed of revascularization of the types of grafts they have used. These observations correspond very well with our experimental findings.

(*Continued on page 814*)

CAUSES FOR AMPUTATIONS PERFORMED AT WALTER REED GENERAL HOSPITAL DURING 1947 AND 1948*

BY COLONEL AUGUST W SPITTLER AND LIEUTENANT COLONEL LLOYD W TAYLOR

Medical Corps, United States Army

In this survey, the cases of 293 patients were studied, who had had a total of 30 extremities amputated Eighty-two of these cases were excluded from the survey fo such reasons as insufficient information available on battle-casualty records, or becaus final results had not yet been obtained on patients still in the Hospital This left a tota of 211 patients studied, in whom 220 extremities had been amputated (Table I) Tw hundred and six of these patients had suffered from battle or other injuries, only fiv

TABLE I

Amputations Performed at Walter Reed General Hospital during 1947 and 1948

Disease or Injury	No of Patients
Vascular disease	
Thrombo-angiitis obliterans	1
Buerger's disease	1
Tumor	
Osteochondrosarcoma	1
Undifferentiated sarcoma	1
Synovioma	1
Injuries from battle	150
Other injuries	56
Total	211

TABLE II

Original Injury to Extremity

Involvement	No of Extremities
Nerve only	3
Bone only	9
Muscle and vessel	4
Bone and nerve	11
Bone and muscle	116
Bone and vessel	6
Bone, nerve, and vessel	3
Bone, nerve, and muscle	24
Bone, nerve, muscle, and vessel	39
Total	215

amputations were for vascular disease or tumor The cases selected for study represent a fair cross section of the amputations performed during 1947 and 1948 at Walter Reed General Hospital

The type of original injury, as to bone, nerve, muscle, or vessel involved, is shown in Table II

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinoi January 27, 1949

TABLE III

NERVE INJURIES IN EIGHTY EXTREMITIES

Nerve Involved	No. of Times Nerve Was Involved
Femoral	3
Sciatic	25
Peroneal	30
Tibial	32
Plantar	3
Brachial plexus	2
Radial	10
Median	11
Ulnar	10
Total	126

TABLE IV

BONE INJURIES

Site of Injury	No. of Extremities
Foot	16
Foot and leg	67
Foot and thigh	1
Foot, leg, and thigh	17
Leg	39
Leg and thigh	24
Thigh	28
Hand	3
Hand and forearm	8
Hand, forearm, and arm	1
Forearm	2
Forearm and arm	2
Total	208

There were nerve injuries in eighty extremities, 126 nerves being affected (Table III). Traumatic amputations were included in this total.

A hand which is completely anaesthetic is a major disability and is a cause for amputation. This is equally true of a foot with a completely anaesthetic plantar surface which ulcerates as a result of weight-bearing. Ten cases of this type were observed, in which the sole cause for amputation was an anaesthetic foot, with areas of local necrosis on weight-bearing, secondary to an irreparable injury to the tibial or sciatic nerve.

The sites of the original bone injury are shown in Table IV. There were bone injuries in 208 extremities in this series.

The major causes for amputation were: gas gangrene, traumatic loss of limb, osteomyelitis, vascular insufficiency, joint lesions, shortening, muscle damage, non-union, an unsatisfactory weight-bearing surface, and paralysis or nerve injury. Other than gas gangrene, traumatic loss of limb, and vascular insufficiency, no single cause listed accounted for amputation. Table V shows the combination of causes.

Amputations were performed upon eight patients because of gas gangrene, secondary to extensive injuries of the extremities. The guillotine amputation had been performed before these patients arrived at Walter Reed General Hospital. Guillotine amputation played an important part in the treatment of the 220 amputated extremities, as evidenced by the fact that a guillotine amputation was performed on ninety-eight extremities at

TABLE V

CAUSES FOR AMPUTATION OF INJURED EXTREMITIES

	No. of Extremities
Osteomyelitis and joint lesion	11
Osteomyelitis and nerve injury	5
Osteomyelitis, joint lesion, and muscle damage	12
Osteomyelitis, joint lesion, muscle damage, and vascular insufficiency	16
Osteomyelitis, joint lesion, shortening, muscle damage, and non-union	30
Osteomyelitis, joint lesion, nerve injury, muscle damage, and vascular insufficiency	18
Osteomyelitis, joint lesion, nerve injury, muscle damage, and unsatisfactory weight-bearing surface	4
Osteomyelitis, joint lesion, and unsatisfactory weight-bearing surface	12
Osteomyelitis, nerve injury, vascular insufficiency, and muscle damage	10
Osteomyelitis, nerve injury, vascular insufficiency, shortening, non-union, and muscle damage	12
Osteomyelitis, shortening, non-union, and muscle damage	35
Gas gangrene	8
Traumatic loss of limb	18
Vascular insufficiency (due to injury)	8
Nerve injury, vascular insufficiency, joint lesion, and muscle damage	6
Nerve injury and unsatisfactory weight-bearing surface	10
Total	215

some time during treatment. Fifty-eight of these were performed at Walter Reed General Hospital and forty at other hospitals.

Although no amputations were performed for osteomyelitis alone, this disease is the major contributing cause for amputation (Table V). The authors believe that sulfonamides and other antibiotics have contributed little, if at all, to the cure of chronic draining osteomyelitis in adults, although they do give systemic benefit during an acute flare-up of osteomyelitis. Adequate surgery and drainage are still the treatment of choice.

Nine patients in this series had both lower extremities amputated; eight of them had been in the hospital from two to four and one-half years to save a defective contralateral limb. The average rehabilitation period after removal of the poorly functioning, painful extremity was less than four months. Amputation of one extremity is not a contra-indication to amputation of a poorly functioning, painful contralateral extremity. The same criteria for amputation should be applied to each extremity.

Sixteen Syme amputations were performed on patients with unsatisfactory weight-

TABLE VI

TIME ANALYSIS OF HOSPITALIZATION

Group	Extremities (No.)	Extremities (Per cent)	Interval between Injury and Amputation (Months)	Average No. of Operations Prior to Amputation	Interval between Final Amputation and Rehabilitation (Months)
A	5	2.3	48 and over	16.4	3
B	5	2.3	42 through 47	12.4	4
C	23	10.7	36 through 41	10.0	4½
D	36	16.7	30 through 35	9.0	3½
E	59	27.4	24 through 29	8.0	4
F	28	13.0	18 through 23	7.0	4
G	8	3.7	12 through 17	7.0	4
H	4	1.9	7 through 11	3.0	4
I	47	21.9	6 or less	2.0	3

TABLE VII

SITES FOR AMPUTATION IN 211 PATIENTS

	No. of Amputations
Upper extremity	
Wrist (disarticulation)	1
Below the elbow	9
Above the elbow	8
Forequarter (interscapulothoracic)	1
Lower extremity	
Ankle (Syme)	16
Below the knee	111
Short below the knee (bent knee)	2
Above the knee	53
Above the knee (supracondylar tendoplasty)	5
Above the knee (Gritti-Stokes)	7
Hip (disarticulation)	7
Total	220 *

* This number includes nine bilateral amputations.

bearing surfaces (Table VII). All of the feet had one or more associated conditions, such as osteomyelitis, joint disease, muscle damage, or nerve paralysis. Nine of the amputations were performed because of failure of full-thickness skin grafts, located on weight-bearing surfaces. Skin grafts applied to weight-bearing surfaces almost invariably fail when they are too massive to receive complete protection by the use of special shoes and supports. Six Syme amputations were performed because of painful, incapacitating feet, for which a complete arthrodesis (ankle fusion and triple arthrodesis) had been performed. A Syme amputee walks better and is less disabled than an adult who has had a foot injury severe enough to require panarthrodesis. Almost invariably these severe foot injuries were associated with traumatic arthritis and periarticular fibrosis of the remaining joints of the feet.

Table VI shows the time interval between the injury and final amputation, but not the months of mental anguish, chronic infection, and conversion reaction, all in the attempt to save useless extremities. Over 75 per cent. of the extremities had been treated for more than a year before amputation, and in each group an average of between 7 and 16.4 operations had been done on the extremity prior to amputation. Over 72 per cent. of these extremities had been treated for eighteen months or longer with a similar range in number of operations. In almost 60 per cent., the patients had spent over two years in hospitals, averaging from 8 to 16.4 operations on the extremity prior to amputation. It can be safely stated that the percentage of successful end results is in inverse ratio to the number of operations required to produce that result.

In the treatment of amputees where an abdominal belt may be required by the prosthesis, bone grafts should be removed from the iliac crest on the same side as the affected extremity. This is because the abdominal belt rests below the contralateral iliac crest, opposite to the amputated extremity.

In twenty-three patients, the fibula had been sacrificed electively in carrying out the planned reconstruction program of the injured extremity. This method of reconstruction is highly unsuccessful and is believed to be unnecessary in the light of the tremendous progress in cancellous bone-grafting in the past ten years.

The sites of amputation are shown in Table VII. As in most series, the below-the-knee amputation was used most frequently; in nineteen of these cases it was necessary to select a higher site for amputation, because the skin was poor as a result of previous operative scars or skin defects. This was particularly true in those cases in which a weight-

bearing type of amputation, such as a Syme, Gritti-Stokes, or supracondylar tendoplasty, could have been performed if good skin had been present

In reconstructive surgery on an injured extremity, the possibility of amputation should always be considered, and operative incisions should be planned so that, if amputation becomes necessary, it can be done at the lowest possible level

CONCLUSIONS

1 Unilateral amputation is not a contra-indication to amputation of the contralateral extremity The criteria for amputation should be the same for each extremity under consideration

2 Skin-grafting of any type to full weight-bearing surfaces is so highly unsatisfactory as to condemn the procedure in general

3 Elective sacrifice of the fibula in a reconstruction program is highly unsatisfactory and unnecessary, in the light of our knowledge of the favorable results from cancellous bone-grafting

4 A Syme amputation is the best major amputation through the extremity It is preferable from a functional standpoint to a complete arthrodesis of the foot, or to any amputation through the tarsal region

5 When amputation is a possibility, surgical incisions should be so placed as to permit amputation at the lowest possible level, should this procedure become necessary at a future date

6 When amputation is a possibility, the removal of cancellous graft from the ilium should be done on the affected side, and not on the contralateral side

7 Needless operative procedures which promised little, if any, possibility of success were performed on the patients studied, causing prolonged months and years of hospitalization psychological trauma, conversion reaction, and general systemic damage, secondary to prolonged periods of chronic infection Early evaluation of these cases and the application of sound surgical principles could have prevented a large proportion of the undesirable problems The principle most often disregarded in these cases was that amputation is a sound method of treatment and not a last resort

DISCUSSION

Dr Rufus H Alldredge, New Orleans, Louisiana Colonel Spittler and Colonel Taylor have made an exhaustive study of the causes for amputations in the Army during 1947 and 1948 They have also called attention to some of the most important fundamental aspects in the care of the seriously injured extremity The authors deserve credit for presenting such an honest statement of the results of surgical treatment which not only failed in the end but often used up several years of the patient's life

We still see an occasional War Veteran who, despite several major operations with good immediate results, finally requests amputation, after having carried on fairly well for several years I agree that it is very important for every case to be carefully evaluated early by experienced surgeons, so that the number of late amputations can be reduced to a minimum

Dr Francis M McKeever, Los Angeles, California The authors have presented over 200 patients, mostly battle casualties of World War II, with severely injured extremities Included are patients with compound, comminuted fractures, extensive soft-tissue damage, and, in many instances, an associated nerve injury and infection After attempts to salvage the extremities of these patients by skin grafts, bone grafts, and nerve sutures, amputation was finally resorted to, these represent failures, in the lexicon of reconstructive surgery It is unfortunate that the authors have not tabulated the percentage of the entire group of battle casualties of World War II which this group of failures represent It is certain that there is a large group of those injured in battle, with extremities injured just as seriously as those reported in this group, who are still using their arms and legs comfortably and satisfactorily, and for whom a well planned program of reconstructive surgery was successful

The point of this paper is, I believe, that a program of reconstructive surgery which is doomed to failure should not be continued indefinitely, when the success of a bone graft and multiple-stage, time-consuming operations will result in an extremity so limited in function by joint stiffness, circulatory insufficiency, and impaired sensation that it is a drawback rather than a benefit The patient should have an amputation

(*Continued on page 819*)

EARLY EFFECTS OF PARTIAL SENSORY DENERVATION OF THE HIP FOR RELIEF OF PAIN IN CHRONIC ARTHRITIS *

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Chronic arthritis of the hip has always been a difficult problem for the orthopaedic surgeon. The many non-operative and surgical procedures which are currently practised are well known and their limitations are recognized. To these procedures may be added the operation of sensory denervation of the hip for the relief of pain. This paper reports the early effects of partial sensory denervation, a procedure which gave some measure of relief from pain to twenty-eight of forty-two patients.

Pain is the major disabling factor in chronic arthritis of the hip, regardless of etiology. Other factors include spasm, deformity, limitation of motion, and weakness. The location, character, and intensity of the pain vary greatly with the individual patient, but there seems to be no correlation between the type of arthritis and the pain pattern. Pain may be constant or intermittent, and may be dull to sharp in quality. Weight-bearing, fatigue, and weather changes usually intensify the pain, while rest, heat, salicylates, and sedatives give temporary relief.

Definite patterns of pain (Fig. 1) can be distinguished.

1. *Obturator Pattern*. The pain is deep in the groin and radiates along the medial aspect of the thigh to the knee. Occasionally it appears to be in the knee, without associated pain in the hip or thigh.

2. *Posterior Pattern*. The pain is in the buttock behind the hip joint, usually without any radiation.

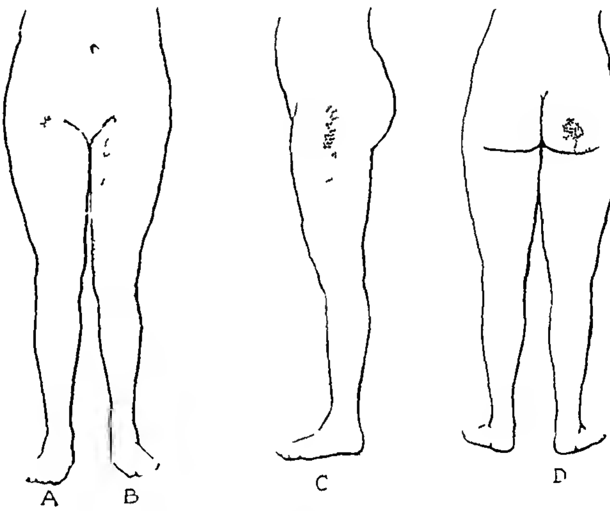

FIG. 1

Common pain patterns in chronic arthritis of the hip.
A. Femoral pattern (anterior). *C*. Lateral pattern.
B. Obturator pattern (medial). *D*. Posterior pattern.

3. *Femoral Pattern*. The pain radiates from the inguinal ligament to the knee, anteriorly.

4. *Lateral Pattern*. The pain is over the greater trochanter and radiates down the lateral aspect of the thigh to the knee.

The obturator pattern is seen in nearly all patients with painful arthritis of the hip; often it is combined with the posterior pattern. The other patterns are rarely encountered except in conjunction with the obturator pattern.

These pain patterns are reflex manifestations of irritation of the sensory nerves to the hip joint. The location of the reflex pain corresponds to the anatomical distribution of the motor components of these nerves in the thigh and buttock.

The hip joint is supplied by articular branches from three major nerves:

1. *Obturator Nerve*. These branches arise from the ventral divisions of the second, third, and fourth lumbar nerves.

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 28, 1948.

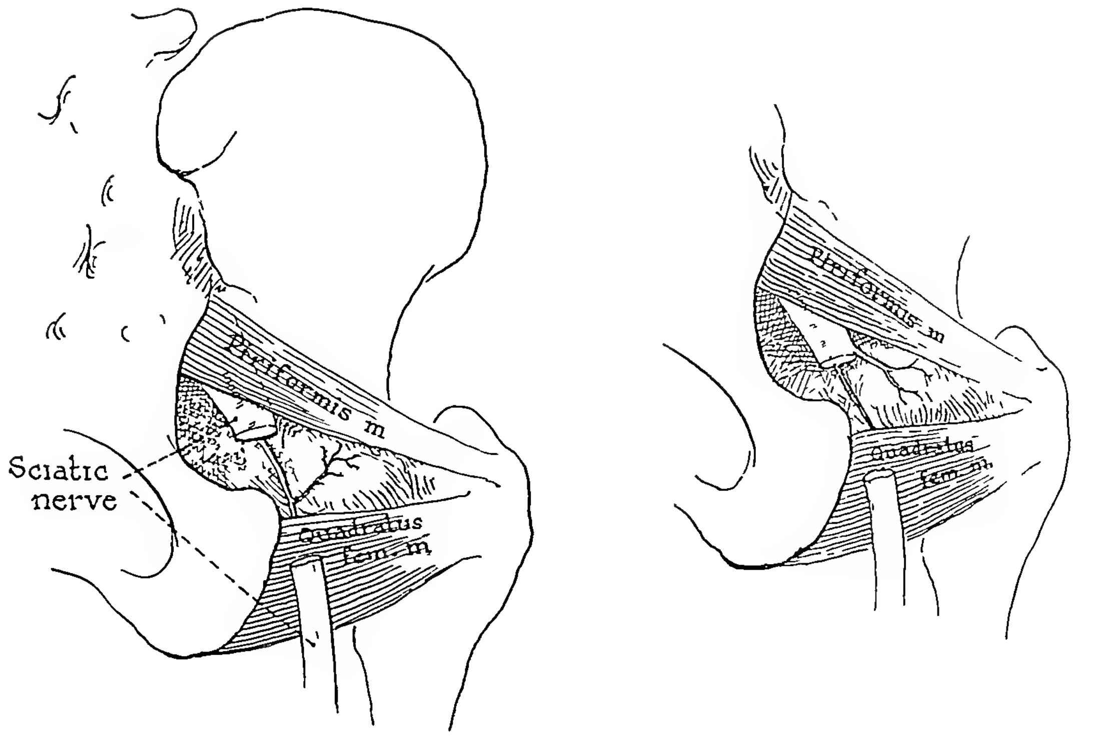

FIG. 2

Posterior sensory nerve supply to the hip joint.

Common pattern is shown at left. The sensory branch arises from the nerve to the quadratus femoris, which is given off by the sciatic nerve.

Anatomical variation is seen at right. The sensory nerve arises as an independent nerve from the sciatic trunk in five of twenty-four dissections performed by Kaiser.

A. *Accessory Obturator Nerve.* These branches arise from the ventral divisions of the third and fourth lumbar nerves, and are present in 20 to 30 per cent of the individuals.

2. *Femoral Nerve.* These branches arise from the dorsal divisions of the second, third, and fourth lumbar nerves, by way of the branch to the rectus femoris.

3. *Sciatic Nerve.* These branches arise from the two ventral divisions of the fifth lumbar and first sacral nerves, by way of the branch to the quadratus femoris.

Anatomical variations in the distribution of the articular branches from the obturator and accessory obturator nerves are reported in detail by Kaiser. His dissections revealed lesser variations in the capsular branches from the sciatic nerve to the posterior portion of the hip joint (Fig. 2). No satisfactory approach to the articular branches of the femoral nerve has been found, and this denervation has not been attempted.

Spasm and contracture of the muscles supplied by the motor components of these nerves produce the flexion, adduction, and external-rotation deformity characteristic of chronic arthritis of the hip. Spasm can be demonstrated objectively by the electromyogram (Figs. 3-A and 3-B). In many of the authors' cases, electromyographic studies were made to determine the presence of tension in the adductor muscles. Recordings were obtained with a six-channel ink-writing oscillograph, which picked up muscle potentials with either surface or needle electrodes. The most effective recordings were obtained when needle electrodes were inserted into the adductor longus muscle of each thigh, the normal side being used as a control. The patient was recumbent in a comfortable position with the thighs supported for complete relaxation.

In normal human muscle in a relaxed state, there is no evidence of electrical activity. Involuntary muscle tension in the form of biphasic spikes was found in a large number of patients with all types of painful arthritis of the hip, tested preoperatively.

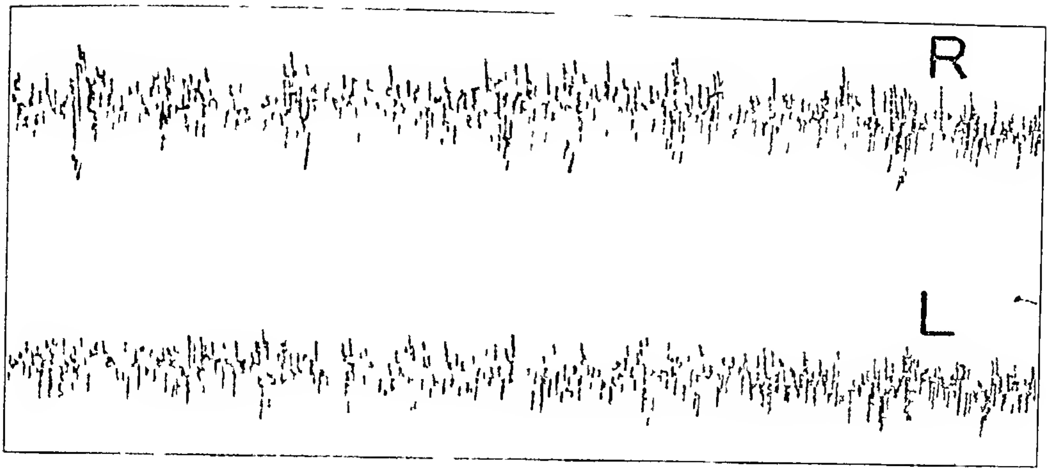

Fig. 3-A

D. O. Electromyographic tracings of spasm in the adductor muscles in a patient with bilateral osteo-arthritis of the hip. Preoperative tracing made on June 17, 1947.

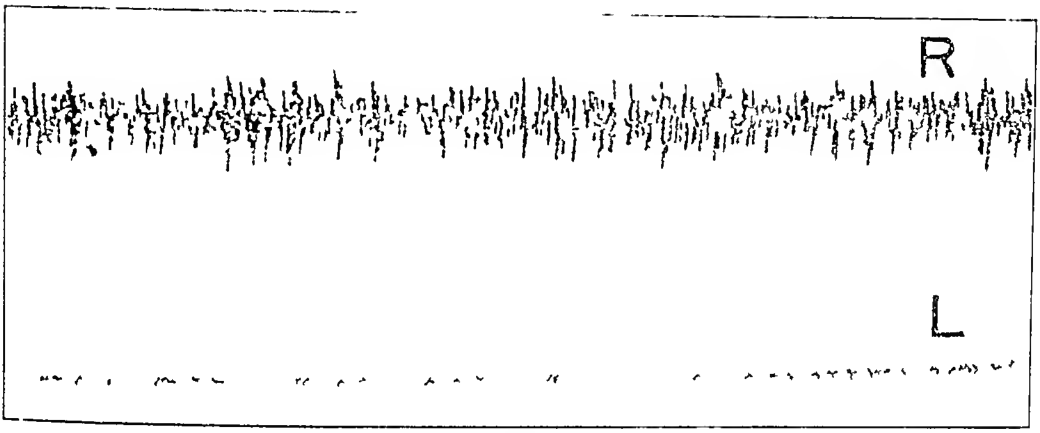

Fig. 3-B

Tracing after intrapelvic section of the left obturator nerve (June 25, 1947).

RATIONALE OF DENERVATION OF THE HIP

Interruption of all pain pathways from the arthritic hip joint to the central nervous system should abolish pain perception. This interruption is possible at different levels and by different approaches. Chordotomy, posterior rhizotomy of the third and fourth lumbar sensory roots, and peripheral sensory denervation of the hip joint have been practised. The least harmful and least difficult operation is that of partial denervation of the hip, which consists of obturator neurotomy and section of the nerve to the quadratus femoris.

Camitz, in 1933, first reported section of the obturator nerve to paralyze spastic adductor muscles in osteo-arthritis of the hip. He was not concerned with interrupting the articular sensory branches of the obturator nerve.

Tavernier and Godinot, in 1945, reported in detail their experience with the surgical treatment of osteo-arthritis of the hip. Between 1934 and 1943, they performed obturator-nerve section on fifty-seven patients. Through an extrapelvic approach, they sectioned the posterior branch and the articular branches of the obturator nerve in twenty-five patients. In the other thirty-two, they sectioned only the articular branches. Immediate results showed relief from pain in forty-five of these patients, but, after a longer observation period, only 38 per cent still had good relief from pain. Between 1943 and 1945, they combined the obturator-nerve section with section of the nerve to the quadratus femoris. Of twenty-four cases, twenty-two had satisfactory relief from pain. Other surgeons have reported their experience with this operation.

Selection of Patients

The patient selected for denervation is one who has the obturator or posterior pattern of pain, not relieved by conservative therapy, in whom standard orthopaedic reconstruction operations are contra-indicated because of old age, feebleness, obesity, or lack of determination, or because the arthritis is bilateral. The long convalescent period and the economic burden associated with these operations further restrict the indications for reconstructive surgery. Partial denervation of the hip can be performed regardless of these contra-indications.

OPERATIVE METHODS

1. *Obturator Neurotomy*

This can be done by either the intrapelvic approach, advocated by Selig and by Chandler and Seidler, or the extrapelvic approach advocated by Tavernier. By the intrapelvic neurotomy, the entire nerve is sectioned before it gives off its sensory branches to the hip. The exposure is extraperitoneal, and is easier to perform than the extrapelvic approach to the nerve. It is particularly applicable to bilateral cases and is the authors' method of choice.

The extrapelvic approach to the obturator nerve has been advocated by Tavernier and his associates, because it permits section of only the sensory branch, without the adductors being paralyzed. According to their writings, the articular branch is given off laterally from the posterior division of the obturator nerve after it leaves the obturator foramen. No such constancy of distribution has been found in the authors' dissections.

A. *Intrapelvic Approach*

The intrapelvic technique employed by the authors varies only slightly from that described by Chandler and Seidler. The same incision may be used for unilateral or bilateral intrapelvic obturator neurotomy.

Before operation, an indwelling catheter is inserted so as to avoid disturbing the urinary bladder. The operation is performed with the patient in the Trendelenburg position, which permits the extraperitoneal portion of the pelvis to be explored more easily. Complete relaxation of the rectus muscles is essential, and can be achieved through the judicious use of curare by the anaesthetist.

A Pfannenstiel incision is made in the pubic fold (Fig. 5), bounded on each side by the linea semilunaris, including the skin, subcutaneous tissue, and superficial fascia. The rectus sheath is split transversely across the body of both rectus muscles or over only one of them, depending upon whether a bilateral or unilateral neurotomy is to be performed. The distal portion of the rectus muscle is then separated from the anterior sheath by compress dissection. After the lateral border of the rectus has been exposed by means of finger dissection, the bladder and peritoneum are reflected posteriorly and medially, the dissecting finger then sweeps out laterally over the obturator foramen, along the lateral wall of the lesser pelvis, until the nerve is palpated. At this point an aneurysm hook is placed about the nerve and it is gently separated from the surrounding structures by blunt dissection. The nerve is pinched with a clamp to evoke contraction of the adductors and to confirm the identity of the nerve before it is sectioned. At least an inch of the nerve is excised between ligatures. The wound is closed in layers.

Care must be observed not to injure the epigastric vessels when the operator is reflecting the bladder and peritoneum posteriorly and medially.

B. *Extrapelvic Approach*

A vertical incision, five inches long, is made in the upper portion of the thigh at a point halfway between the femoral artery and the symphysis pubis (Fig. 4). The subcutaneous fat is divided and the vaginal fascia of the thigh is split in the line of the incision

This exposes the lateral border of the adductor longus and the adjacent border of the pectineus. These two muscles are separated and retracted. The obturator nerve is easily found in the interval between these muscles. The anterior branch lies between the adductor longus and the adductor brevis, which is just beneath it. It is traced proximally until the obturator foramen is reached. The obturator nerve divides into anterior and posterior branches usually after leaving the obturator foramen. Lateral branches from either the anterior or posterior branches are looked for and, when found, are divided. The anterior and posterior branches are cut as close to the obturator foramen as possible, and about one inch of the nerve is resected. The incision is then closed in layers.

2. *Posterior Denervation*

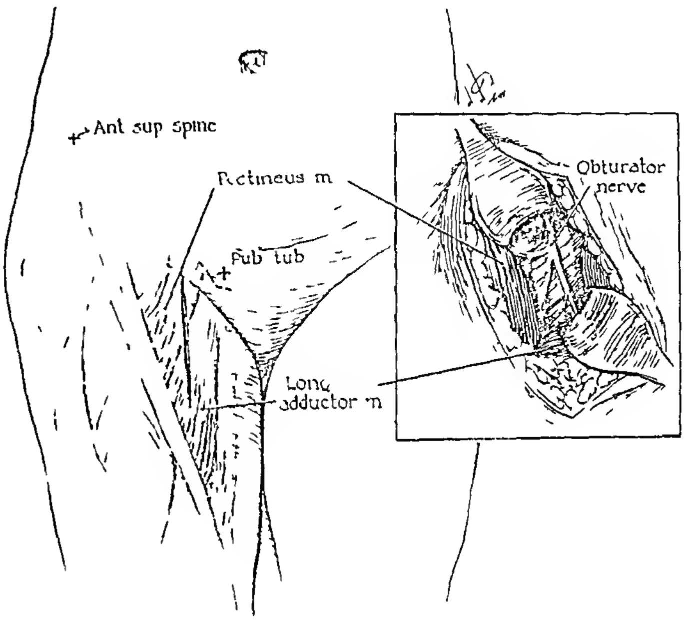

Fig. 4

Extrapelvic technique of obturator neurotomy

The skin incision is made in the distal two thirds of the line drawn from the posterior superior spine of the ilium to a point halfway between the greater and lesser trochanters (Fig. 6). The subcutaneous fat is divided in this line to expose the gluteus maximus. The fibers of the gluteus are split bluntly in their long axis starting at the greater trochanter. The entire depth of the muscle is divided and retracted forcibly, exposing the subgluteal fatty areolar tissue, in which can be seen the sciatic nerve. The nerve is not disturbed, but the fat covering the quadratus femoris, inferior gemellus, obturator internus, superior gemellus, and piriformis at the intertrochanteric line is divided to expose these muscles. A blunt instrument is introduced under the insertions of the gemelli and obturator internus, and these muscles are divided close to their insertions. They are then reflected upward and medially as far as possible, being best peeled off the underlying hip capsule by compress dissection. Very little bleeding is encountered.

These muscles, when reflected, serve to protect the sciatic nerve from injury. The posterior portion of the hip capsule is thus exposed, with the broad quadratus femoris forming the lower border of the operative field. The nerve to the quadratus femoris can often be palpated as a cordlike structure which runs perpendicular to the muscle and enters the undersurface of the muscle near the ischium. The nerve lies directly on bone and is covered by a very dense fibrous fascia, so that sharp dissection is required to mobilize it. When the nerve has been exposed, it is pinched with a hemostat and the quadratus femoris is seen to contract. The nerve is then cut at the border of the muscle and gently freed proximally by incising the overlying dense fascia. Branches from this nerve to the hip capsule are looked for and, when found, are divided. The nerve is traced back as far as possible, until its origin from the underside of the sciatic nerve is reached or until it disappears under the piriformis. The nerve is divided as high as possible.

The nerve to the inferior gemellus is found, entering the undersurface of the reflected muscle, and is cut at its insertion and traced proximally as far as possible. This nerve may also give rise to articular branches.

Occasionally a large sensory branch comes off the sciatic nerve, just above the nerve

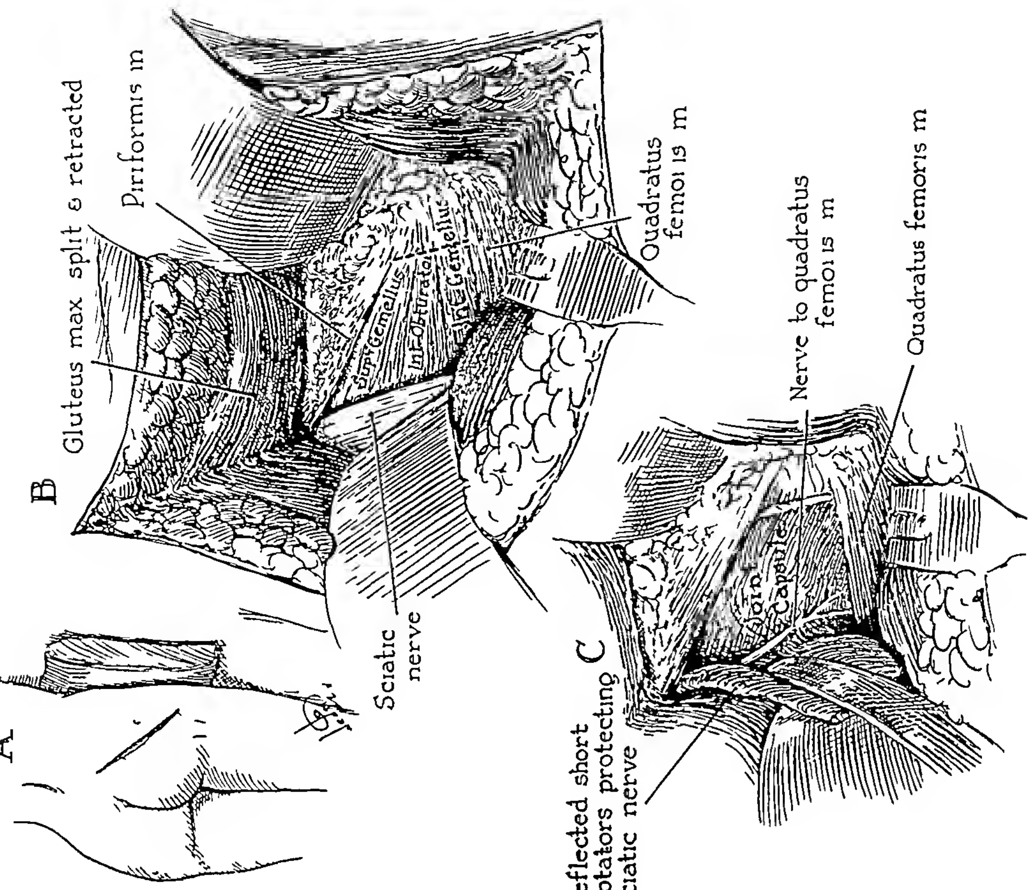

Fig 6
Posterior denervation of the hip by section of the nerve to the quadratus femoris

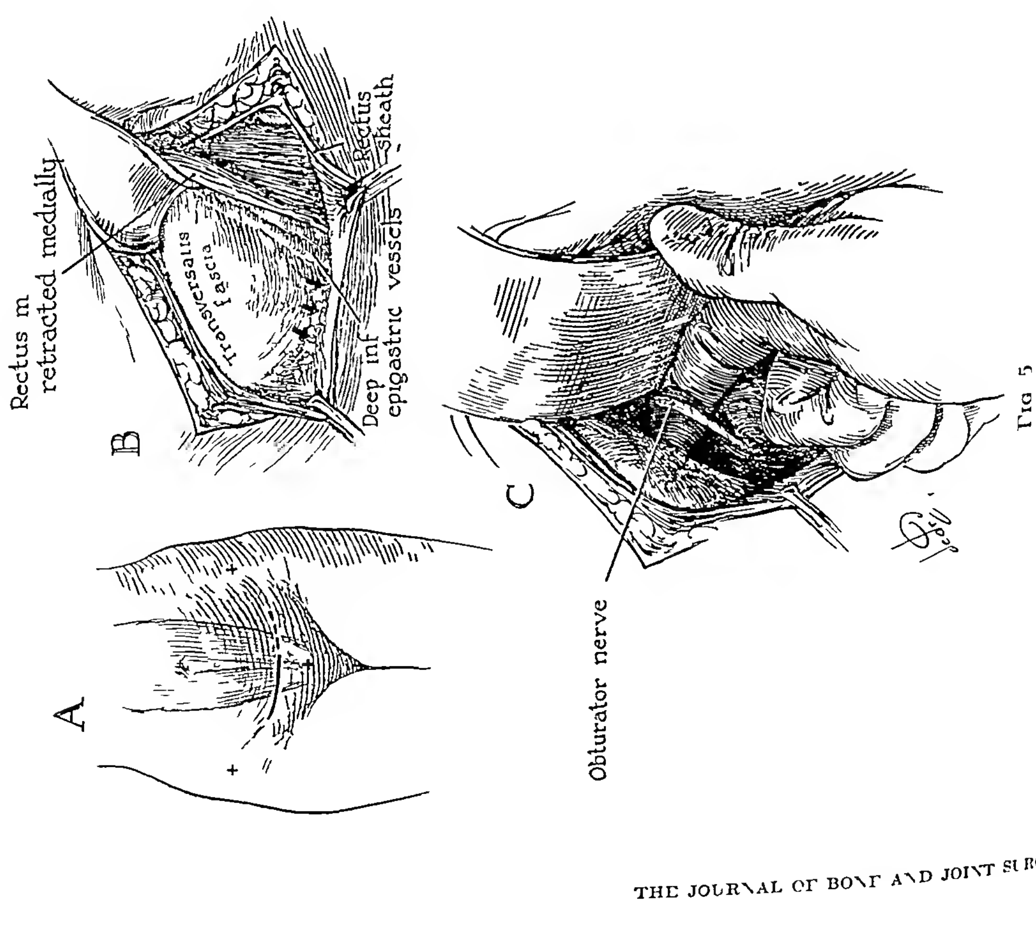

Fig 5
Intrapelvic technique of obturator neurotomy

TABLE I

ETIOLOGICAL FACTORS, AGE, AND NUMBER OF FAILURES

	No. of Patients	Average Age (*Years*)	No. of Failures
Osteo-arthritis	24	65	8
Rheumatoid arthritis	5	47	1
Marie-Strümpell disease	3	45	1
Aseptic necrosis			
Post-traumatic	3	40	1
Idiopathic	1		
Congenital dislocation	2	38	2
Old Perthes' disease	1	40	1
Totals	42		14

to the quadratus femoris, and runs parallel to this nerve as far as the hip joint, where it divides into small branches and enters the hip capsule. This nerve must be looked for and, if found, resected. It was present in five of twenty-four dissections made by Kaiser[4].

The divided and reflected rotator muscles are then sutured to their place of insertion at the greater trochanter. The gluteus maximus fibers come together easily, and the thin overlying fascia is sutured loosely. Subcutaneous and skin closures are performed in the usual manner. No drains are needed.

The intrapelvic obturator neurotomy and posterior denervation are performed as one operation, bilaterally if desired. The postoperative care is simple, and the patient may sit up or even get out of bed on the day after the operation. The usual period of hospitalization is from eight to ten days. No serious operative complications have been experienced.

This report is based upon experience with partial denervation of forty-eight hips in forty-two patients, treated between May 1946 and October 1947 (Table I). In all instances the arthritic changes in the hip joint were well advanced clinically and roentgenographically. Conservative therapy had been tried without benefit in all of these patients. The

TABLE II

OPERATIVE PROCEDURES

	Relief	No Relief
Obturator neurotomy		
Intrapelvic	10	2
Extrapelvic	10	11
Posterior denervation	2	0
Combined one-stage partial denervation	6	1
Totals	28 (67%)	14

earliest cases were treated only by extrapelvic obturator neurotomy. After several failures, the authors changed to the intrapelvic obturator-nerve section with better results. In patients with the obturator pattern of pain, only the intrapelvic obturator-nerve section appeared to give relief. Two patients with the posterior pattern of pain were relieved by posterior denervation alone. Patients with the obturator pattern plus posterior or other patterns of pain were subjected to the combined operation of intrapelvic obturator neurotomy plus posterior denervation. Some of these operations were done in two stages, and it was possible to evaluate the early effects of the obturator neurotomy before the posterior denervation was performed. In the last seven patients the combined operation was per-

formed in one stage, with satisfactory relief of pain in six patients (Table II). In this series, no attempt was made to locate and section the accessory obturator nerve.

EARLY EFFECTS OF PARTIAL DENERVATION OF THE HIP

Not enough time has elapsed to permit a final evaluation of the results of this operation. Since they were based on an observation period of from three to twenty months, we can record our impressions only of the early effects. It is hoped that further observation and experience will permit a more valuable end-result study.

Pain

Accurate evaluation is not possible, because of the subjective nature of the response. Complete relief from pain is rarely acknowledged, but partial relief is accepted with gratitude by most patients in whom the operation succeeded. Residual postoperative pain is usually of a milder character and a different pattern than the preoperative hip pain. Patients with the obturator pattern of pain may get relief from obturator neurotomy, only to be aware of pain of lesser intensity in other locations about the hip joint.

An estimate of the relief from pain may be obtained by the diminished need for aspirin or sedatives, or by the degree of relief noted by other members of the family when the patient is recumbent, sitting, or walking. Some patients, who felt no improvement in the hip pain when walking, reported relief while at rest. Most reported that they slept better.

The earliest effect of the operation on pain is seen almost as soon as the patient recovers from the anaesthesia. Pain in the operative areas does not mask the relief from deep hip pain. Radiating thigh pain disappears, along with a feeling of tenseness in the thigh.

Range of Motion

In very few of the patients has there been a measurable increase in hip motion after this operation. Most, however, have been able to abduct their legs better and to assume a broader stance. Others reported that they were able to put on their shoes and stockings after the operation, a procedure prohibited previously by pain. This was a welcome improvement.

Spasm

The patient is aware of relief from tension in the adductor region as soon as he recovers from the anaesthetic. This is verified by postoperative electromyographic tracings, which show almost complete disappearance of the previously observed spontaneous muscle activity.

Strength

One detrimental early effect of the obturator neurotomy is the weakness in flexion of the hip in a few patients, due to the loss of reinforcing flexion action of the adductor longus and adductor brevis. This weakness has not added to the disability of these patients.

Sensation

Postoperative neurological examination showed an area of diminished sensation over the medial aspect of the thigh, just above the knee, in a few patients. They complained of numbness in this area.

Deformity

The operation has not corrected any existing deformity. Undoubtedly the persistent attitude of flexion, adduction, and external rotation is due to fixed contractures, and is not influenced by the release of spasm of the involved muscles. Irregularity of the articulating surfaces of the hip joint also influences the deformity and this, of course, is not altered by the denervation procedure.

Shortening

Shortening is not influenced by the operation

Joint Changes

Follow-up roentgenograms have not disclosed any changes in the arthritic process More time will be needed to evaluate the effect of the operation on the course of the arthritis of the hip

In fourteen of the forty-two patients, absolutely no relief from pain was experienced Most of these failures were in patients treated by the extrapelvic obturator neurotomy Reoperation was not done The authors could not predict success or failure in any patient before surgery

CONCLUSIONS

Partial denervation of the hip has been performed for the relief of pain in various types of chronic arthritis of the hip This operation consists of an intrapelvic obturator neurotomy and section of the nerve to the quadratus femoris It is relatively easy to perform and produces no constitutional reaction so that it is applicable to a large group of patients

Of forty-two patients with painful arthritis of the hip who were thus treated, satisfactory relief from pain was obtained in twenty-eight The longest postoperative observation period was twenty months When obturator neurotomy alone was used for the relief of pain, it was found that the intrapelvic approach was more effective than the extrapelvic operation Eleven of the fourteen failures in this series were treated by extrapelvic obturator-nerve section Lack of consistently satisfactory results may be attributed to anatomical variations in the sensory nerve supply to the hip

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DISCUSSION

DR EMANUEL B KAPLAN, BRONX, NEW YORK Dr Obletz' paper is very interesting and timely This method, which was initiated in Sweden and used widely in France, is a useful one We had a patient with Marie Strumpell disease upon whom we tried the method in 1945, by the extrapelvic route, on one hip The patient felt so well that he asked us to do the operation on the other side The result was so satisfactory that he returned to his work as a gardener Since then we have operated upon fifty-four patients, the results of which will be published shortly, and we have now operated upon twenty more We have used only the extrapelvic method, because it appeared more simple It is important to place the incision along the lateral border of the adductor longus in order to locate the obturator nerve in the interspace between the adductor longus and the pectineus It is easy to identify the two branches of the nerve in the areolar tissue in this area

The posterior route, which we have used in three cases only, is slightly more difficult As Dr Obletz said, it is necessary to extirpate the nerve to the quadratus femoris We use a slightly different approach, which we think is simpler With the apex of a semicircle over the greater trochanter, one branch goes down to the femur and the other is almost parallel to the fibers of the glutaeus maximus Through this incision we cut the femoral insertion of the glutaeus maximus This is an area where bleeding occurs Bleeding is much

easier to control when the glutaeus maximus is freely retracted We have to be extremely careful becau the inferior gluteal artery may be injured, resulting in severe bleeding

This method opens new horizons as to understanding of pain in joints We all think that the ordinar articular nerve branches are going the way they have been described by Dr Obletz and many anatomi t Not much is known about the microscopic endings of those nerves We have absolutely no idea how the pai stimuli are carried to the central nervous system Investigations show that rhizotomies and peripheral nerv section do not prevent the experimental animal from having painful sensations as a result of irritation of tl extremities

In the posterior approach, Dr Obletz divides not only the nerve to the quadratus femoris, but also th external rotator muscles, in the anterior approach, the nerve supply to the adductor muscles It is possibl that he thus interrupts the sensory nerves to the muscles and the motor nerves, which would amount t indirect tenotomies

Dr J Albert Key, St Louis, Missouri I have used this operation for over fifteen years for pain ii the hip Roy Abbott and others use it for spastic conditions of the adductor muscles The intrapelvic ap proach was described by Selig about 1915 The reason that it has not been discussed in the American litera ture is probably because the results are so uncertain In many cases the results are satisfactory, but one can not predict what will happen when an obturator neurectomy is done for the relief of pain

The operation is relatively simple, but the obturator muscles cannot be denervated without producing weakness of the adductor muscles If both branches are cut, the patients are unable to cross their legs whil sitting, they lack endurance in walking, and some of them lack stability For that reason I have felt that I would return to the external route and cut only the deep or posterior branch If there is a strong adductor contracture, I divide both branches Dr Reynolds and I have reported twenty cases done by the intrapelvic route, sixteen patients had what we thought were satisfactory results over a short period, but none of them have been operated upon for longer than two years Many of those whom we regarded as satisfactory have a weak limb

For several years I have combined the obturator neurectomy with a Smith-Petersen acetabuloplasty and have obtained more satisfactory results than with either operation alone The more I operate on these old painful hips in older people, the more I am inclined to consider that the best therapy is a cane or a crutch. That you can depend on, with rest If the patient will not rest and demands an operation, obturator resection is a relatively simple procedure and it usually gives about 50 per cent relief of symptoms It does not give complete relief, and it may leave objectionable weakness of the extremity

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DISCUSSION

Use of Homogenous Bone and of the Merthiolate Bone Bank

(*Continued from page 799*)

I should like to correct Dr Wilson in that we claim no infection in a clean case, but have had per i tent drainage in infected cases Experimentally and clinically, there has been no evidence of tissue sensitivity o toxicity from aqueous merthiolate solution, used as a preserving agent for bone

Dr James B Weaver (closing) It is a privilege to have my paper discussed by such eminent authorities as Dr Inclán and Dr Wilson I am in complete agreement with Dr Inclán's remarks

Dr Wilson feels that I am somewhat discouraged Let us say that I am not so enthusiastic as I was one time, but this change is for the better One of my first cases was the last one reported in my paper (Ca 6-S),—the repair of a large bone defect in the tibia, caused by osteomyelitis The result was truly remarkable, and led us to use preserved homogenous grafts with the expectation that they would accomplish mo than we had ever expected from autogenous grafts This was based on the assumption that an ample supp of graft material might offer a greater chance of success This assumption is in part true, but basic princip in bone-graft surgery must be observed I am continuing the use of preserved homogenous grafts

This is a small series and the statistics are apt to be misleading This is particularly true if one no only the percentage, and does not take into consideration the large number of difficult cases

OBTURATOR NEURECTOMY FOR COXALGIA

An Anatomical Study of the Obturator and the Accessory Obturator Nerves

BY ROBERT A. KAISER, M.D., BUFFALO, NEW YORK

From the Department of Orthopaedic Surgery, Edward J. Meyer Memorial Hospital, Buffalo, and the Department of Anatomy, University of Buffalo School of Medicine

The anatomy of the hip joint in terms of its nerve supply has, in recent years, received much attention. This has been directly due to the reports of Tavernier and his associates indicating that surgical attack on the sensory fibers to the hip joint from the obturator nerve and the nerve to the quadratus femoris could not only be accomplished, but was attended by good results in patients with painful hip disorders. In the elderly, frequently obese patient with coxalgia, biologically unsuited for a major surgical procedure such as arthrodesis, these operations appeared to offer a simple solution for a difficult problem.

Frequently, however, the operating surgeon does not seek out the capsular fibers, but contents himself with the less tedious task of sectioning either the obturator nerve or the nerve to the quadratus femoris, feeling secure that his level of section is above the point at which capsular fibers are given off. This approach makes the evaluation of these operations difficult. Successful results could be attributed to factors other than depriving the capsule of part of its sensory innervation. Relief might be obtained, following surgery, from the accompanying denervation of deforming muscle masses (adductors and external rotators), thus relieving spasm or correcting muscle imbalance.

Until a large series of cases have been reported in which surgical attention is directed exclusively to the sensory fibers to the capsule, and an equally large control series are studied in which the sensory fibers are avoided, but the muscular branches are severed, the results will be questionable. Before either of these studies can be accomplished, it becomes necessary to scrutinize certain aspects of the neural anatomy of the hip joint.

Obturator Nerve

In current, standard anatomy texts and recent publications, one finds not only a divergence of opinion regarding the capsular fibers, but a certain vagueness about their course and distribution. The anatomies of Gray, Grant, Morris, Cunningham, and Piersol cite the anterior branch of the obturator as the source of the sensory fibers. Piersol's *Anatomy* mentions, in addition, a branch from the posterior. The fibers are described variously as going to the hip joint, the acetabular notch, or the anteromedial portion of the capsule. Tavernier and Godinot favor the posterior branch as the most frequent point of origin for these fibers which, they state, supply the anterior portion of the hip capsule, the head of the femur, and the acetabulum. Kaplan, on the basis of twenty-four dissections, found that the capsular branches of the obturator nerve came, most frequently, from the common obturator trunk in the obturator canal. Gardner confirmed this observation after seven complete and four partial dissections of adult joints in addition to the study of serial sections of four foetal joints.

In an effort to obtain a more exact and detailed picture of the nerves to the hip joint from the obturator and accessory obturator nerves, dissections were undertaken. Four preliminary exercises were done to determine what method of attack might best lend itself to the demonstration of these branches. Finally the following procedure was adopted. Cadavera were transected through the lumbar and upper femoral areas and then split sagittally through the mid-line. The peritoneum and pelvic organs were stripped from these hemipelves, and the obturator nerve was traced from its emergence from behind the psoas muscle to the obturator canal. The iliopsoas was reflected laterally, and the

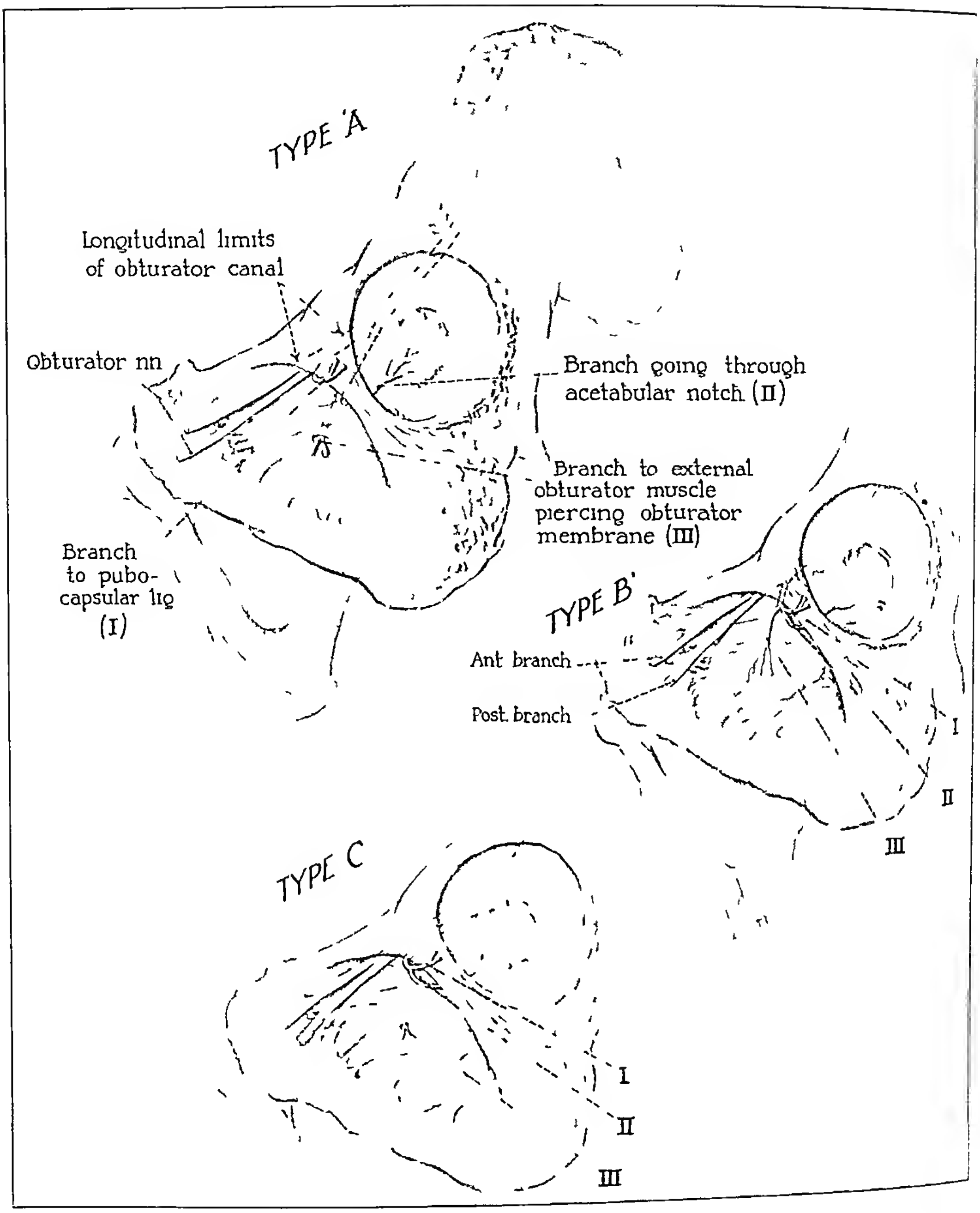

Fig 1

Three basic patterns of innervation of the pubocapsular ligament and the acetabular notch from the obturator nerve

region of the iliopectineal eminence was inspected for an accessory obturator nerve Th obturator internus and its fascia, in each instance, was carefully freed from the obturat membrane to facilitate the tracing of those branches which took origin in the pelvis Aft all relationships had been observed, the horizontal ramus of the pubis was removed, t canal was cleared of fat, and the fibers picked up to this point were followed to the terminations Twenty-four dissections were done in this standard fashion Most of t specimens were photographed for future reference, and a few of the finest filaments tra to the capsule were subjected to histological study, to be sure that dissection continu could be relied upon No statistical values can be derived from such a small number observations, but the findings seem to be of some clinical value

Two branches of the obturator nerve were frequently encountered, which dem description and re-emphasis In reference to hip-joint innervation, these are much m important than either the anterior or the posterior branch The first has been de

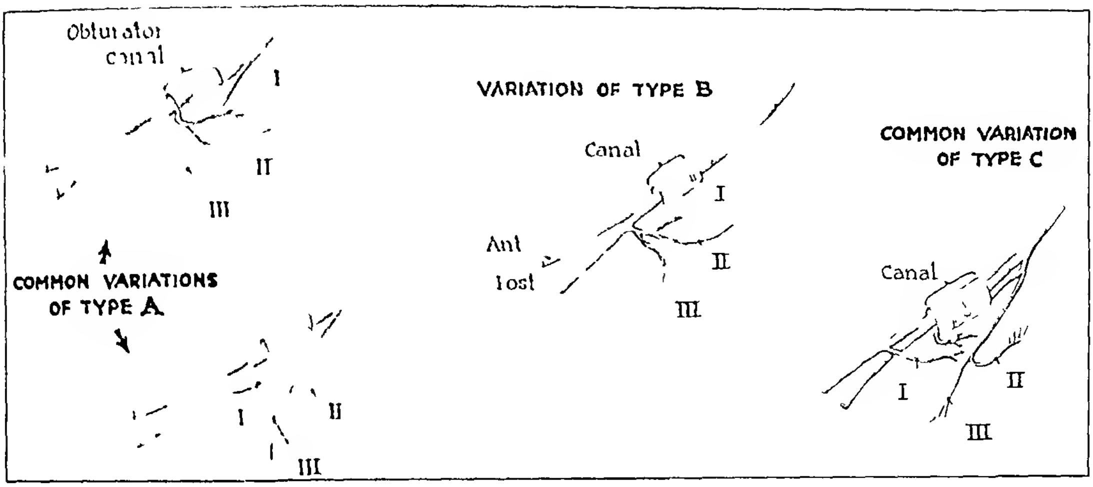

Fig. 2

Variations of the three basic patterns.
I. Branch to the pubocapsular ligament.
II. Branch going through the acetabular notch.
III. Branch supplying the obturator externus.

by Kaplan and by Gardner, it takes its origin from the obturator nerve in the canal, from whence it passes, hugging the lateral bony aspect of the passage, to the pubocapsular ligament which is directly adjacent to the outlet of the obturator canal.

From time to time this branch had a double destination, supplying the capsular area and then passing posteriorly over the transverse acetabular ligament and into the acetabular notch, presumably to supply the ligamentum teres. *One should not get the impression that this branch is consistently given off near the outlet of the canal, for it may be found leaving the obturator nerve anywhere in the canal and, as a matter of fact, frequently is found at the inlet of the passage. Nor should one feel that the nerve becomes clearly visible simply by tracing the anterior or posterior branch back to the common trunk.*

The second branch of prime importance is large in size and quite constant; it was present in eighteen of the twenty-four specimens. It originates from the obturator nerve inside the pelvis. In one instance it was found leaving the main nerve as far as 3.5 centimeters from the mouth of the obturator canal. The usual course of this branch is to the entrance of the canal, at which point it dips down between the obturator internus and the obturator membrane, piercing the latter to supply the obturator externus. Frequently a filament is given off before the obturator membrane is passed, which courses directly to the acetabular notch. In six instances this branch bifurcated within the pelvis. One component accompanied the common trunk through the canal to supply the pubofemoral ligament. The other pursued the usual path to the obturator externus. In these instances the acetabular notch was supplied by either branch.

Consideration of the variations (Fig. 2) will make clear that infrequently the anterior or the posterior branches do supply the capsule. This confirms the findings, but not the frequency, recorded in standard texts and by Tavernier and Godinot.

The detailed findings of the dissections are presented in Figures 1, 2, and 3. For the sake of simplicity, the patterns of innervation have arbitrarily been broken down into three basic types, *A*, *B*, and *C* (Fig. 1). *Type A* was found six times. In two instances the general arrangement was the same except that the single branch to the pubocapsular ligament came not from the common nerve, but from the posterior branch. Another variation occurred three times,—the branch to the pubocapsular ligament supplied the acetabular notch as well. *Type B* was observed four times. One variation occurred in a specimen in which the posterior branch supplied the pubocapsular ligament and the acetabular notch. *Type C* was present four times. A variation was found in two hips in

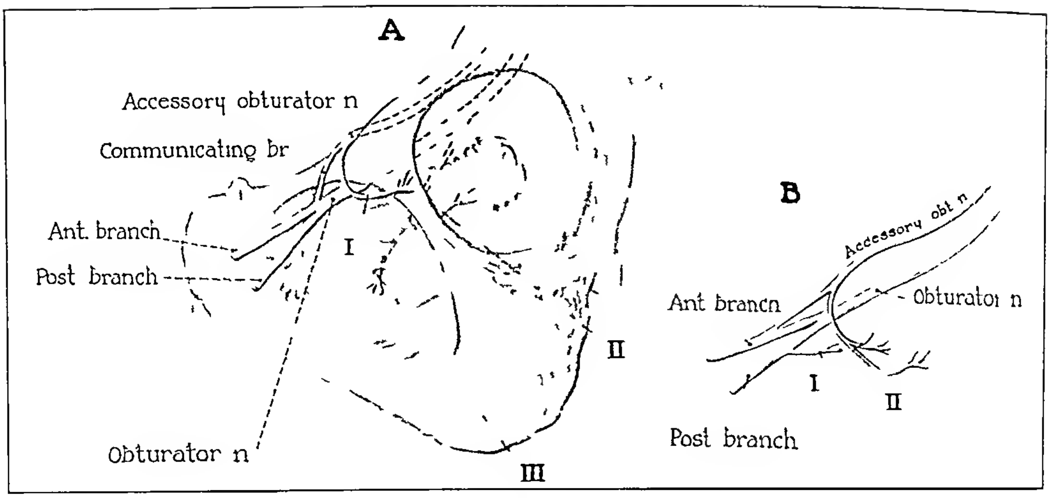

FIG. 3

Accessory obturator nerves
I Branch to the pubocapsular ligament
II Branch going through the acetabular notch
III Branch supplying the obturator externus

which the acetabular notch was innervated by a filament from the nerve to the obturator externus. The pubocapsular ligament was supplied, not only by a branch derived endopelvically, but also by a filament from the anterior branch of the obturator nerve.

Accessory Obturator Nerve

The accessory obturator nerve is reported to occur in from 19 per cent[8] to 29 per cent of cases[6]. There is general agreement that this nerve, when present, supplies the capsule of the hip joint. In only two specimens was this structure present (Fig. 3). In *A* the accessory obturator splits and gives a branch to the common obturator nerve, while the other branch lavishly supplies the pubocapsular ligament. The branch to the acetabular notch is derived from the nerve to the obturator externus, which took its origin within the pelvis. In the second specimen (*B*) one branch of the bifurcated accessory obturator fuses with the anterior branch of the obturator. The other courses not only to the pubocapsular ligament, but also to the acetabular notch. In this dissection, an additional branch to the pubocapsular ligament from the posterior branch of the obturator nerve was in evidence.

In these two instances the capsular area supplied by the accessory obturator was about the same as that supplied by the obturator alone. This is at variance with the statement of Gardner: "When the accessory nerve is not present, this region of the capsule is reached by the femoral nerve . . . ."

COMMENT

It would seem from this study that the nerve supply to the hip from the obturator and accessory obturator nerves is a trifle more complicated and variable than has generally been indicated. It would appear that the extrapelvic approach to the capsular branches is inadequate. In those instances where the exit of the obturator canal is adequately explored and the capsular fibers are identified and sectioned, there is still a good possibility that the nerve to the acetabular notch is present. Also, the presence of an accessory obturator nerve must be kept in mind.

If the intrapelvic approach is utilized, one has an excellent chance of sectioning the obturator nerve above the point where the sensory fibers are given off. However, without exploration of the region of the iliopectineal eminence for an accessory obturator, as recommended by de Sousa, one cannot be sure that the sensory area of the capsule sup-

plied by the obturator and accessory obturator nerves is denervated. There is a remote possibility that, due to poor exposure or poor hemostasis, the obturator nerve could be sectioned near or at the mouth of the obturator canal, with the large branch to the obturator externus originating endopelvically (which may supply the acetabular notch and the pubocapsular ligament), going free.

NOTE: The author wishes to thank Benjamin E. Obletz, M.D., for his encouragement of this project, and Oliver P. Jones, Ph.D., Professor and Head of the Department of Anatomy, University of Buffalo School of Medicine, for the materials used and advice given. Appreciation is also given to Mr. M. Diedrick for his careful attention to the illustrations.

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DISCUSSION

CAUSES FOR AMPUTATION

(*Continued from page 804*)

rather than endure the psychological devastation and economic loss resulting from a long period of hospitalization and multiple surgical procedures, and then finally have an amputation. Particularly is this the case when only one extremity is involved. With this, I am in accord. However, immediate or even early decision to amputate an injured extremity is often wrong. Many times, such a decision cannot be made intelligently for many weeks or months after the injury, particularly in young individuals. Often the decision cannot fairly be made until a program of reconstruction has been tried and has failed during some phase of its development.

I feel that the authors' statement that the fibula is useless in reconstruction of the leg is not tenable. True, the fibula in an adult cannot be expected to take over the entire weight-bearing function of the tibia, as it will not become hypertrophied to that degree. In many instances, however, a synostosis of the tibia with the fibula will immensely simplify and reduce the extent of the necessary bone-grafting and make bone substitution a more probable success. The use of the fibula in a synostosing operation also may permit use of a leg with a brace, which is still far superior to an amputation for many people.

While unilateral amputation may not be a contra-indication to the amputation of the second extremity, in my opinion it certainly makes the criteria for amputation of the second extremity much more stringent. A bilateral below-the-knee amputee may be very agile, but he is the exception rather than the rule. There are many bilateral above-the-knee amputees who left Service Hospitals on prostheses and canes, with their chins up, who are not using their prostheses at all today, and who are not ambulatory. I believe that a second extremity should not be amputated until the patient is thoroughly convinced that it is a detriment to him.

The authors are to be congratulated for pointing out the necessity for careful planning and foresight before starting an extensive program of reconstruction which may take years and accomplish nothing for the patient.

PROCAINE INJECTION FOR RELIEF OF PAIN IN THE HIP

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The control of pain in the arthritic hip has always been a difficult problem for tl orthopaedic surgeon The work of Taverniei and Godinot, Mallet-Guy and de Mourgue and Ricard and Francillon has demonstrated that pain in the hip can be relieved by surg cal section of the obturator nerve and the nerve to the quadratus femoris The possibilit of procaine injection of these nerves was suggested to the authors by Steindler Landmarl and the technique of injection were worked out on cadavera

TECHNIQUE

The obturator nerve is injected with the patient in the supine position and the a fected extremity in slight abduction, if possible The pubic tubercle and the femoral arter are palpated, a mark is made at a point halfway between the two, and a thumb's breadt beneath the inguinal ligament Digital palpation at this point will determine the superio ramus of the pubis The needle is inserted until it strikes the superior ramus It is thei withdrawn a short distance and tilted so that, as it is reinserted, it passes along the inferio surface of the superior ramus to the obturator foramen In the majority of cases the patien will complain of pain, radiating along the anteromedial aspect of the thigh At this point 10 cubic centimeters of 1 per cent procaine is injected and the needle is withdrawn

For injection of the nerve to the quadratus femoris, the patient is placed in the prone position with the involved hip in as much external rotation as possible The landmark are indicated with a suitable dye, such as gentian violet A straight line is drawn from the lower end of the sacrum to the posterior superior spine of the ilium A point is marked at the junction of the lower and middle thirds of this line Another point is marked on the lateral surface of the buttock, about one inch posterior to the greater trochanter and on a level with the lower end of the sacrum A wheal is made at this site, and a long, dull needle is inserted The needle is directed toward the point indicated on the line between the tip of the sacrum and the posterior superior spine and, as it is inserted, it is tilted to form an angle of approximately 45 degrees with the table (Fig 1) The insertion is continued until the needle strikes bone If it has been directed properly, the tip will be against the posterior surface of the body of the ischium, just lateral to the sciatic nerve The dull point of the needle is then carefully "worked" medially along the bone for another 1 or 2 centimeter

FIG 1

During injection of the posterior nerve supply to the hip, the needle is inserted at an angle of 45 degrees with the table

Frequently this will reproduce the hip pain Fifteen cubic centimeters of 1 per cent procaine is then injected slowly The point of the needle, being against the body of the ischium, allows the procaine to be diffused along the broad, flat surface of this bone, upon which lie the nerve to the quadratus femoris and its articular branches

RESULTS

Twenty-three patients have been treated by this method The underlying cause of the hip pain in these patients included osteo-arthritis in eleven cases, congenital subluxation with hypertrophic arthritis in four cases, ununited fracture of the femoral neck in three cases, previous arthroplasty in two cases, congenital dislocation of the hip with an old shelf operation in one case, old Perthes disease with arthritis in one case, and old, quiescent atrophic arthritis in one case

Nineteen patients had immediate and complete relief from pain, both when at rest and during motion, after the first injection Four patients had little or no relief In two of hese four, complete relief from pain followed a second injection, the next day The other wo were discharged from the Hospital before reinjection was attempted These failures are considered to be due to technical errors

In addition to loss of pain eighteen of the patients showed an increase in motion in he involved hip In several cases there was an immediate decrease in the degree of flexion and of adduction contracture The improvement in mobility of the hip frequently was associated with disappearance of pain in the lower portion of the back The five patients who did not gain in motion included the two who failed to obtain relief from pain and hree whose lack of increased mobility could be explained on the basis of a mechanical block

Four patients complained of pain in the knee on the affected side examination of the nee revealed no local cause for pain One of these patients had an ununited fracture of the emoral neck, the others had osteo-arthritis of the hip The pain in the knee was considered o be referred in nature, originating in the hip Each of these patients experienced relief f pain in the knee as well as in the hip following procaine injection

The duration of relief from pain following a single procaine injection varied from hirty-six hours to three months, the period of relief apparently had no relationship to he severity of the symptoms

DISCUSSION

It is the authors' impression that the increased motion of the hip and the diminution f the flexion-adduction contracture following procaine injection are due to relief from ain and to release of reflex spasm of the involved muscles No explanation is offered for he prolonged absence of pain following a simple procaine injection However, such an xperience is not foreign to those who have used procaine injection of the sympathetic anglia for such painful syndromes as Sudeck's atrophy or causalgia

Selective nerve injection is a definite and useful addition to the methods now available or the treatment of pain in the hip It is not claimed that relief from pain is permanent owever, the result is immediate and the pain may be absent for an indefinite period of me The procedure is simple and harmless, and may be repeated It is useful in the atient who is a poor operative risk, and in those for whom arthroplasty or arthrodesis is ndesirable It may also be used as a therapeutic test before surgical denervation of the hip

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ELECTROMYOGRAPHY IN ORTHOPAEDICS*†

BY ARTHUR L WATKINS, M D, BOSTON, MASSACHUSETTS

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The orthopaedic surgeon is regularly confronted with the problem of evaluating disorders of neuromuscular function Although locomotion, strength, and skill can be tested fairly adequately for clinical purposes without elaborate apparatus, there are many cases in which diagnosis and prognosis can be ascertained with greater accuracy if muscular activity is analyzed in a more detailed manner Electromyography has now been developed to a point where conclusions can be drawn as to its usefulness to the orthopaedic surgeon in the better understanding of some of the complexities of neuromuscular disease

CONDITIONS IN WHICH ELECTROMYOGRAPHY IS OF VALUE

Poliomyelitis

Considerable interest exists as to the nature of muscle hyperirritability or "spasm" in acute and convalescent poliomyelitis The clinical features are well known, but for their explanation investigators have turned to the electromyographic laboratory Numerous reports from widely separated clinics have indicated the presence, in patients with acute poliomyelitis, of abnormal electrical activity in muscles at rest (Fig 1), whether they have normal strength or are weakened [4,21,24,31] The completely paralyzed muscles, on the other hand, are electrically silent, with exceptions to be noted later Change in position or passive stretching has been found to produce strong discharges from the muscles in spasm, corresponding to the clinical findings of pain and tenderness This type of electromyographic tracing resembles that recorded from muscles splinting a painful joint, secondary to fracture We cannot say, however, whether or not the mechanism is the same or even similar, as the electromyogram gives information only as to the amount and character of peripheral activity What is occurring in the central nervous system must as yet be left to conjecture

Some of the hypotheses which have been suggested are

1 The disease, which frequently involves the dorsal root ganglion, may incite sensory discharges which, in turn, cause reflex muscle spasm in the corresponding segment

2 Irritation of the anterior horn cells themselves may produce hyperactivity of the corresponding motor units

3 Disease of the internuncial neurons may decrease normal inhibitory spinal-cord activity, thus allowing hyperactivity of the lower motor neurons [17] It has been impossible so far to perform the crucial experiments clinically, to differentiate these possible mechanisms or others which may be acting

After the acute stage of the disease, when the signs of meningeal irritation have disappeared, much of this electrical hyperirritability also becomes diminished or is absent Even muscles that are tender to pressure show little abnormality electrically, except for those which are only partially paralyzed In this case a different type of electromyogram is usually observed A resting muscle in the position of maximum relaxation shows spontaneous high-voltage, low-frequency discharges which are only slightly increased by stretching (Fig 2) The same muscles, on attempts at voluntary motion, discharge action potentials of relatively low frequency and irregular low voltage Their appearance is similar to the discharges recorded from muscles partially innervated from peripheral-nerve injuries, particularly during the stage of regeneration of nerves (Fig 4) This type of

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† Aided by a grant from the National Foundation for Infantile Paralysis, Inc

FIG 1

Passive plantar flexion in acute poliomyelitis Showing hyperirritability after passive stretching

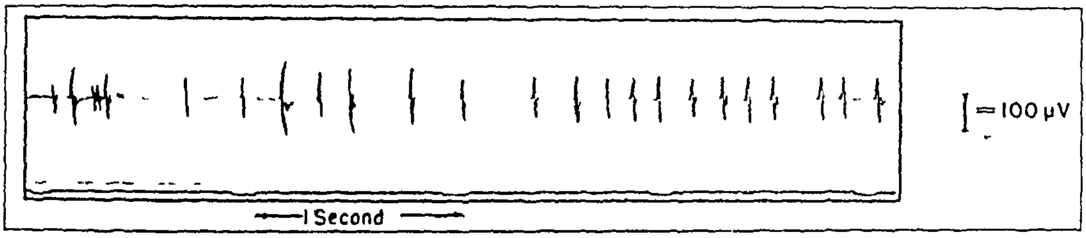

FIG 2

Partially weakened muscle with impaired innervation Spontaneous electrical discharges in resting muscles are an indication of the survival of partially functioning nerve fibers in acute poliomyelitis

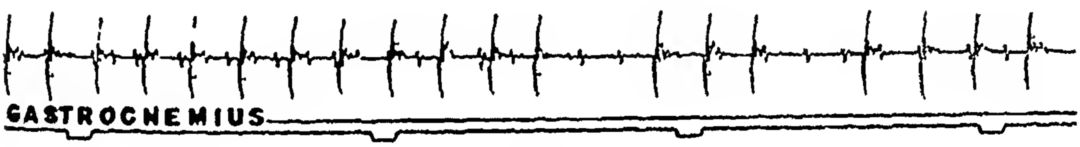

FIG 3

Spontaneous discharges from resting paretic muscles during stage of increasing strength

discharge has been recorded months or years after the onset of the disease, and is generally correlated clinically with a state of improving muscle strength (Fig 3)

A further type of spontaneous discharge from resting muscles is quite different These potentials are of extremely low voltage and short duration, with irregular and inconstant frequency Their appearance is that of fibrillation, recorded from denervated muscles in the case of a severed peripheral nerve[13] This type of fibrillation cannot be recorded satisfactorily with ink-writing electromyographs, the cathode-ray oscilloscope and photographic film being more suited for this purpose (Fig 5)

Electromyography has demonstrated a further type of neuromuscular disorder in patients with poliomyelitis This is the co-contraction of muscles of antagonistic function during attempts at voluntary motion[29] (Fig 6) This is a type of incoordination or substitution which may disappear with training in muscle re-education It may represent some synaptic dysfunction in the spinal cord, or simply be a poorly organized attempt to produce motion from many muscle groups when there is a considerable degree of weakness

Electromyograms may also be used as a rough quantitative measurement of voluntary power during active contraction of muscle[23] There is a correlation between muscle strength and the voltage of action potentials, although it probably is not so trustworthy a quantitative measurement as an ergogram Because of this approximate quantitative measurement which is possible, electromyography has been used to evaluate the effectiveness of various physical agents on the degree of muscle spasm in poliomyelitis Results to date, however, have been negative, there being no strong preference for any of the physical agents commonly used, including intramuscular prostigmine[30]

FIG 4

Fig 4 Discharges from resting muscles during early reinnervation after injury to brachial plexus

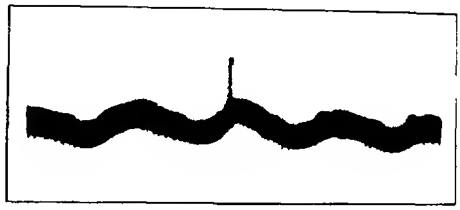

Fig 5 Fibrillation of denervation in relaxed paralyzed muscle Total length of record is 1/10 second, height of potential is 50 microvolts

FIG 5

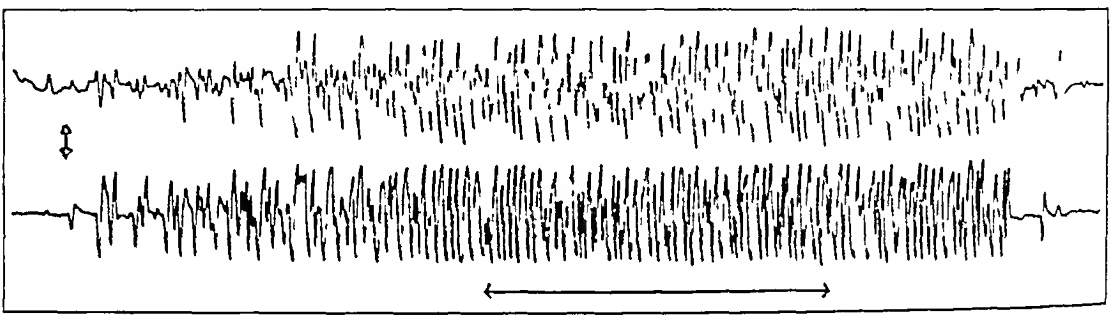

FIG 6

Co-contraction of paretic muscles with antagonistic action during voluntary flexion of elbow Upper record is of biceps, lower record of triceps Calibration horizontal arrow, 1 second, vertical arrow, 50 microvolts

It is concluded that in poliomyelitis (1) electromyography gives a rough quantitative measurement of muscle spasm and strength, (2) disorders of normal reciprocal innervation can be detected, (3) high-voltage, spontaneous discharges at rest are consistent with a favorable prognosis for improvement [28], and (4) fibrillation denervation potentials are a poor prognostic sign [13]

Peripheral-Nerve Injuries

Electromyography has been used extensively in the study of peripheral-nerve injuries during the past ten years It has been found possible by this method to detect early signs of reinnervation before there is clinical evidence of regeneration, and to determine the extent of nerve damage, particularly in cases of compression or stretch injuries, where the presence of action potential indicates that the lesion is not complete [6, 20, 27] It is also useful where there is suspected hysteria or malingering, as normal potentials may be discharged from a muscle which is apparently paralyzed The greatest value of electromyography is probably in following the course of regeneration of peripheral nerves to determine the extent of reinnervation of muscles

Ruptured Intervertebral Discs

In patients with pain in the upper extremity and suspected protrusion or rupture of a cervical intervertebral disc, electromyograms have shown the presence of discharges from resting muscles, presumably from irritation of cervical roots [3] In the case of disc lesions, these discharges are often increased with movements of the neck By reference to the common root supplying the muscles from which this abnormal activity is recorded the electromyogram has been found an aid in localization of the lesion (Fig 7) Simil

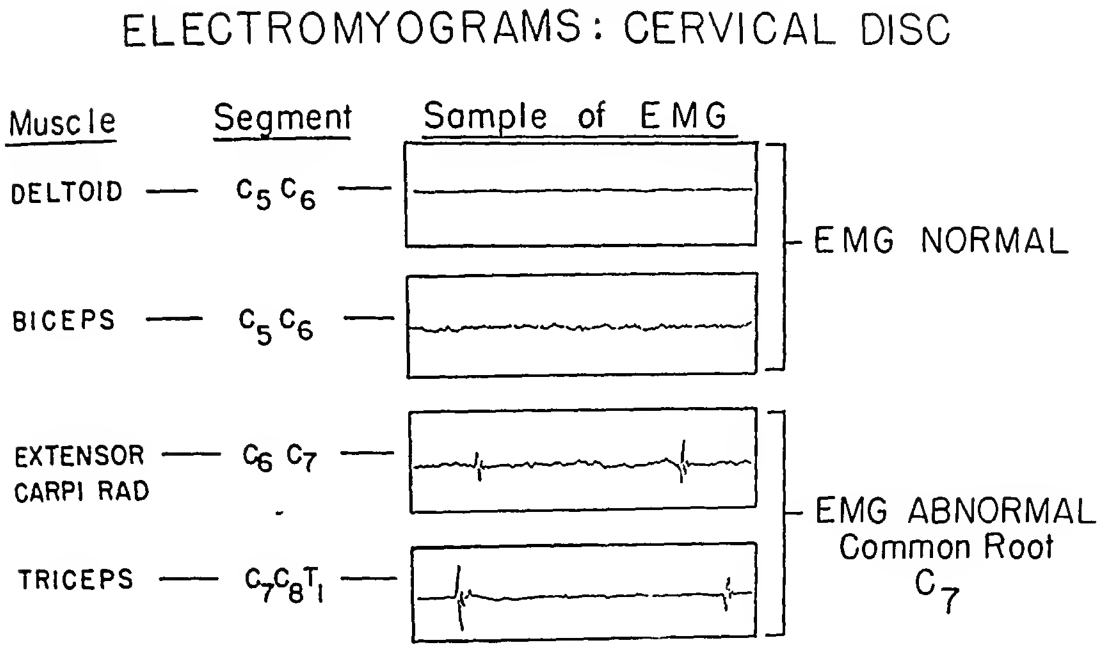

FIG 7

Spontaneous discharges from resting muscles of patient with proved protrusion of intervertebral disc

electromyographic tracings can be obtained from patients with lumbar intervertebral-disc lesions The tracing, of course, does not give a specific diagnosis of disc lesion, but simply suggests irritation of one of the lumbosacral roots Because of the overlap of segmental innervation of the muscles of the leg, the electromyogram is of less value in localizing the level of the lesion

Progressive Muscle Atrophy and Amyotrophic Lateral Sclerosis

In these progressive degenerative diseases of anterior horn cells, the electromyogram shows a very characteristic abnormality (Fig 8) Spontaneous discharges in these conditions produce diphasic spikes of very irregular voltage and frequency They are often

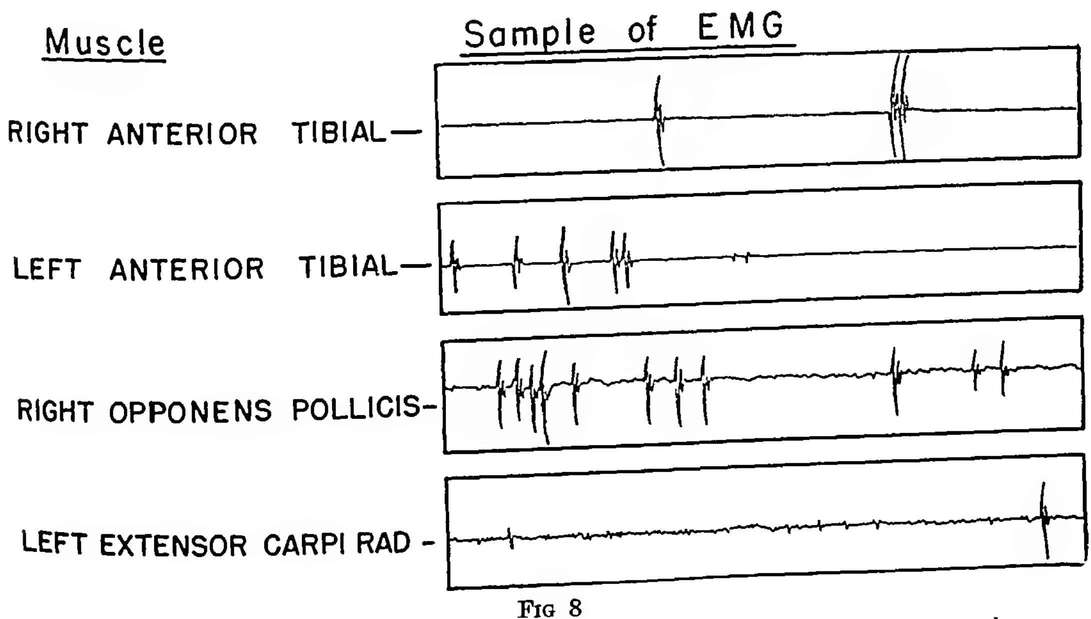

FIG 8

Resting muscles Note irregular frequency, voltage, and widespread distribution of potentials in progressive muscle atrophy

picked up from muscles free of visible fasciculations, so that a general diffuse degenerative disease may be detected at an early stage, when clinical signs reveal only localized muscle atrophy. The amount of electrical activity is also correlated to some extent with the rapidity of progress of the disease process.

Parkinson's Disease (Paralysis Agitans)

Electrical recording of the tremor characteristic of Parkinson's disease is so constant that the electromyogram is of diagnostic importance.[22] There are found to be alternate

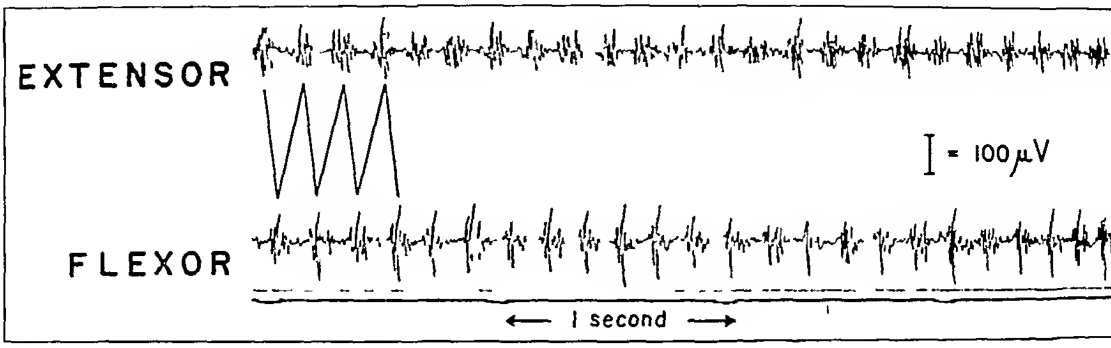

FIG. 9

Parkinson's disease. Showing rhythmically alternating bursts of action potentials.

discharges from antagonistic muscle groups with a regular frequency of about six per second, the bursts of electrical activity having a fairly normal appearance as to frequency and voltage (Fig. 9). As this type of tremor can rarely be reproduced voluntarily, it is possible to differentiate such tremor from that of hysterical origin.

Spasmodic Torticollis

Patients with spasmodic torticollis show diffuse high-voltage discharges from the muscles involved, as would be suspected from clinical examination. The amount of electrical activity may be used to evaluate the effectiveness of various therapeutic agents, such as drugs or locally injected chemicals.

CONDITIONS IN WHICH ELECTROMYOGRAPHY IS OF LITTLE OR NO VALUE

Muscle Dystrophy

There is no characteristic abnormality of the electromyogram in muscle dystrophy. No fibrillation potentials are recorded, there simply being a gradual decrease in the amount of voltage discharged during voluntary action. The completely paralyzed muscles are electrically silent.

Myasthenia Gravis

Although the fatigue characteristic of myasthenia gravis can be demonstrated by means of electromyography, the records do not have an appearance which is specific for this disease, so that it is not an important diagnostic tool.

Spasticity

The hyperactivity of the stretch reflex in patients with cerebral palsy, hemiplegia, and spinal-cord disease can be demonstrated electromyographically by passive stretching. Such electromyograms, however, simply confirm a condition which is obvious upon clinical examination. The degree of spasticity present can be roughly determined quantitatively for purposes of evaluation of therapeutic agents, but this is not exact quantitation, as the electromyogram simply records a small sample of muscle activity,—namely, the muscle

fibers in the proximity of the recording electrodes[18]. It is also impossible to get a quantitative picture of the spasm present in the muscles supporting the hip joint, because of their distance from the skin. Although needles may be inserted into some of these muscles, the sample obtained is a very small portion of the large muscle mass present.

RESEARCH

As electromyographic equipment is expensive and, until recently, was not available on a commercial basis, it has been used largely in research laboratories. Abundant literature on the subject, however, has accumulated, and a few examples related to orthopaedic conditions will be cited. Seyffarth, Lindervold, and Jasper have studied the behavior of motor units in healthy and paretic muscles, particularly in poliomyelitis. Recordings made during well-coordinated movements in normal individuals are also of interest, particularly analyses of the action of individual muscles during voluntary movement of the shoulder and hip[2, 11, 15, 26, 30, 31]. Muscle activity after transposition of the tendon in cases of poliomyelitis has also been the subject of investigation by Weiss and Brown. Spasticity, rigidity, and involuntary movements have been examined extensively, and electromyography has been used to determine the effect of various new drugs for control of this abnormal motor activity[1, 6, 9-12]. One of the most recent techniques devised for clinical use is that related to transmission of the nerve impulse to muscle, by Harvey and Masland, and Hodes and his associates. This opens up a large avenue for further research, which should help elucidate still unsolved problems of neuromuscular dysfunction.

SUMMARY

1. Electromyography has been found useful in studying the pattern of motor activity in normal and paretic muscles, particularly in poliomyelitis and peripheral-nerve injuries.

2. Degrees of spasticity, rigidity, and tremor may be measured semi-quantitatively by this method.

3. Information of diagnostic importance is obtained from patients with progressive muscle atrophy, Parkinson's disease, peripheral-nerve injuries, and hysteria.

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DISCUSSION

DR J E MARKEE, DURHAM, NORTH CAROLINA It is a privilege and pleasure to comment on this fine paper Discussors with clinical experience should elaborate on the usefulness of electromyography as a mean of determining whether certain muscles or portions of muscles are contracting or in spasm Dr Watkins and other students of electromyography should be encouraged to extend the scope of the study of muscle potentials as a technique of delineating an area that is contracting Our experimental studies are of interest in this connection only because they indicate that the area from which a muscle potential arises coincides with the area of actual shortening

Certain theoretical considerations which have arisen in our work with muscle potentials in exposed muscles of the dog may be of interest in a discussion of investigations of this type Our evidence indicates that the strength of summated muscle potentials is proportional to the number of neuromuscular units which are contracting The strength of the muscle potential is also proportional to the nerve potential, at least in th

experiments involving isolated muscle twitches in a restricted number of exposed muscle fibers. On the other hand, the muscle potential is not proportional to either the work accomplished, or the tension that is developed, except in so far as the number of units is involved.

By measurement, the muscle potential from a given number of contracting units was not increased, even though the amount of work accomplished was experimentally increased tenfold. Likewise, as long as the number of contracting units was unchanged, there was no appreciable change in the muscle potential, even though the amount of tension developed by these contracting fibers was changed tenfold or even twentyfold. That is, in our experiments, a given number of fibers had about the same potential, first, when they were already short and could produce little tension and, second, when they were partially stretched and capable of producing much greater active tension. Our evidence indicates that the summated muscle potential is a measure of the number of units contracting.

If our experiments can be extended and confirmed, it may be necessary to conclude that the strength of the muscle potential is only a measure of the number of units contracting. On the other hand, manual or ergographic testing supplies information about the efficiency of the contraction, and is not necessarily a measure of the number of units contracting.

If these theoretical considerations can be proved and extended to the human, it should be possible to acquire more useful information about some patients and to improve the care of patients with certain muscle ailments. For example, it might be possible to apply this information to the understanding and care of patients with poliomyelitis. If the muscle potential is purely a measure of the number of units contracting, it should follow that a measurable summated potential from a given muscle would increase throughout convalescence only as long as additional neuromuscular units are recovering. Thereafter, there should be no increase in the intensity of the summated muscle potential, even though the strength of the muscle is increasing as measured by muscle strength, manual testing, or ergographic testing.

If these assumptions are true, the summated potential from a muscle should also give a measure of the number of contracting units in Parkinson's disease and in a number of the other pathological states mentioned by Dr. Watkins. Obviously, adequate apparatus is wanting for most studies of this type.

Much additional information can be made available in the preoperative and postoperative study of muscles, if further studies confirm our evidence that the strength of the potential arising from a muscle is purely a measure of the number of units that are acting. Time limits even the listing of the possible applications to patient care. These possibilities can be explored only through cooperative investigations in the clinics and experimental laboratories.

Dr. R. Plato Schwartz, Rochester, New York: In this as in many other subjects, one's interest can exceed understanding. However, because of personal interest in the application of electromyography to the behavior of the neuromuscular mechanism, I am grateful for the privilege of discussing Dr. Watkins' paper. He has provided evidence which reaffirms previous observations. This is an important contribution, because the relationship between electromyography and orthopaedic surgery is still young. Many more such observations will be needed before the resulting values become generally accepted.

Dr. Watkins has made new and interesting observations. It is hoped that these will be confirmed by others who are equally capable in this field of investigation. Some comments on the illustrations which he presented are as follows*:

Figure 2, showing a record of spontaneous motor activity in poliomyelitis, confirms previous observations. A higher degree of irregularity in timing and in excursion is commonly observed in such records. Also, the output of 50 microvolts is noted as low in the wide range of 0 to 5,000.

Figure 1, a passive stretch record, is typical of previous observations. The record appears to have been made with a pen motor. There is good separation between the high and low peaks, but the magnitude of I = 50 microvolts strongly suggests that the recording system may have been overloaded. We also noted a series of equally spaced deflections, which we have observed when the pen motor was not following the impulses from the muscle, but was following those frequency components close to its resonance frequency. Therefore, the record revealed the resonance frequency of the pen motor rather than the variable frequency of the muscle impulses.

Essentially the same interpretation can be made of Figure 3. The calibration of I = 100 microvolts should not have a significant influence. In our experience, both 100 microvolts and 50 microvolts are rather low calibrations for the recording of a strong stretch reflex.

Figure 4 is the spontaneous discharge in a resting muscle in association with a fractured elbow. This record shows successive groups of deflections of essentially equal variation in amplitude and uniformity of spacing. Here we may again be observing the characteristics of a record produced by a pen motor, when the pen responds to frequencies approaching its own resonance frequency. Since time and calibration data were not included in the illustration, however, it is not possible to evaluate this record on that basis.

* The illustrations as published are not in all cases those discussed by Dr. Schwartz, although similar, the calibrations differ. Figure 4, mentioned by Dr. Schwartz, has been omitted. Figure 5 corresponds to Figure 4 in the published article.

Figure 5 shows the spontaneous activity of resting muscle in association with a brachial-plexus injury This record seems to be exactly as described in Dr Watkins' paper,—that is, similar to records frequently obtained from resting muscles in the acute stage of infantile paralysis

Figure 6, of poliomyelitis, is typical of the type of response which we have frequently observed in records made on patients in the acute stage of infantile paralysis However, the record presented is slightly confusing for the want of data The relationship of voluntary flexion and extension to the tibialis anterior and gastrocnemius was not indicated However, the principle is clear The voluntary contraction of the agonist sets up a simultaneous counter contraction in the antagonist

Figures 7 and 8 are electomyograms of the cervical disc and of amyotrophic lateral sclerosis We have not made electromyograms of patients with either of these diagnoses, for this reason we have no special comments regarding these records

Figure 9 The characteristics of this record of Parkinson's disease reveal a classical pattern which can be duplicated by records taken from our own files In many instances we have noted that our step-down pattern and the flat baseline are both distorted by other impulses from the muscle, superimposed on those which provoke the tremor These superimposed impulses have been associated with clinical evidence of rigidity, which is frequently noted in this disease It is, therefore, important to differentiate between the simple Parkinsonian tremor and the recorded characteristic of this tremor plus rigidity This is not too difficult, because *in either case the timing of the bursts associated with the tremor remains essentially constant*

This lack of information can be summed up in the statement that there are insufficient data to permit other laboratories to attempt to duplicate these results

Statements are made by Dr Watkins regarding the possibility of roughly quantitating muscle strength through the measurement of electromyograms While this statement is categorically true, it must be recognized that several factors can create a degree of "roughness" so large as to make any quantitative expression useless In Figure 1, which has previously been mentioned, the high spikes and general pattern of the deflections suggest the same type of difficulty we have experienced when calibrating at 300 microvolts per centimeter The high spikes shown in this record are almost certainly records of pen-motor overswing and would, therefore, bear no relationship to the magnitude of the associated muscle impulses There is also evidence of pen-motor resonance

On the positive side, three statements can be made regarding the illustrations presented in this paper These are common to similar papers from other sources, and are as follows

1 Electromyograms are capable of revealing the presence or absence of muscle activity in normal and pathological conditions

2 Discrimination can be made between continuous muscle activity, voluntary or involuntary, as shown in Figures 3 and 9, respectively In general, it is not possible to distinguish between voluntary and involuntary impulses when they form a continuous pattern, such as that shown in Figure 6 Voluntary and involuntary records are shown on the same chart, and there is nothing to distinguish them In the case of tremors, however, such as that shown in Figure 9, it is generally accepted that involuntary impulses produce a uniform sequence that is impossible to duplicate intentionally

3 Under carefully controlled conditions, with known interelectrode distances, constant electrode size and a calibration level sufficiently high to preclude the possibility of overloading the amplifiers, and at frequencies which do not provoke resonance in the pen, correlation is possible between the amplitude of the electromyogram and the strength of the muscle producing the impulse This has been found, however, to be more reliable at the lower levels of activity It is, of course, necessary to change the calibration value in proportion to the amount of effort exerted

These statements are based upon similar limitations which we have noted in the course of our own efforts to correlate the characteristics of electromyograms with the clinical evidence of abnormal muscle function Such efforts will probably be continued by us and by others From these combined experiences will come a definition of principles as related to instrumentation, technique, and interpretation of electromyograms in orthopaedic surgery For these reasons we should be grateful to Dr Watkins and should encourage continuation of his work

Dr Arthur L Watkins (closing) I should like to thank the discussors for their enlightening remarks concerning the work done on electromyography in their laboratories Dr Schwartz has raised the question of overloading of the recording pen We have not been using, I believe, a pen motor of the type Dr Schwartz has tested In any case, our recording system has been tested specifically for overloading Using monophasic 2-millisecond impulses, no overswing occurred with an input overload of ten times, this also held true with diphasic impulses Tests were performed with increasing power and frequency Again no overshooting was observed with frequencies from 50 to 150 cycles per second No problem of pen resonance was encountered in this frequency range

HEMANGIOMA OF THE KNEE JOINT

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Although hemangioma of the knee is rare, it is deserving of attention by the orthopaedic surgeon, because of the challenge which it presents in differential diagnosis. Approximately thirty authentic cases of this entity have been reported in the literature; of this number, less than five were diagnosed correctly prior to arthrotomy. With a better understanding of the clinical picture as related to the underlying pathological condition, the percentage of correct diagnosis before surgery can probably be increased greatly.

This paper presents two cases of cavernous hemangioma of the knee joint.

CASE 1. P. H., a white male, aged seventeen, was first admitted to the Hospital on January 22, 1944. An initial attack of pain and swelling had followed immediately after injury to the right knee, eight years previously, but the symptoms had subsided spontaneously in a few days and joint function was completely restored. During the intervening years, similar episodes had occurred, with or without minor injury; there had never been evidence of inflammatory involvement. The knee had been treated by his local doctors and by specialists in a large eastern city. Because of the recurrent nature of the disease and the increasing severity of the attacks, hospitalization had been advised.

At the time of examination, the right knee joint was distended by a moderate amount of fluid. The muscle atrophy at the thigh was minimal, and the joint could be carried through a normal range of motion except that the extremes of flexion and extension caused some discomfort. The skin overlying the joint was entirely normal, and the inguinal glands were free of involvement.

Roentgenograms revealed a small, ill-defined area of increased density within the anterior compartment of the joint. This was seen best in the lateral view, with the knee flexed about 10 degrees beyond a right angle.

Because of the involvement of a single joint, the chronicity of the process, and the progressive nature of the disease, an arthrotomy was performed. After the capsule had been entered through a medial parapatellar incision, it was noted that the synovial membrane had been invaded and distended by a bluish lobulated mass, which was attached to the membrane at the postero-inferior margin of the patella. This tissue was extirpated with little difficulty, hemorrhage not presenting a problem to the operator. The pathologist reported a cavernous hemangioma of the knee joint.

The patient's extremity was immobilized in plaster for two weeks after operation and, aside from a slight amount of effusion, the knee recovered without incident. After a period of active physical therapy, joint function was completely restored.

Six weeks following discharge from the Hospital, the patient returned for a series of deep roentgen treatments; he received a total of 1,200 r through two portals. More than four years have elapsed since the operation, and this patient is entirely free of symptoms. He is very active in athletics and describes the knee as normal.

CASE 2. M. P., a white woman, aged thirty-five, was admitted to Charlotte Memorial Hospital on December 31, 1945. She had injured her left knee twenty years previously, while skating. Attacks of pain and swelling had recurred intermittently since the injury, and had been most frequent during the six to eight months preceding admission.

Examination showed that the swelling was more prominent in the medial compartment of the knee; a small granular mass could be palpated in this area, overlying the medial femoral condyle. Slight tenderness was present; the inguinal glands were not affected. Measurement of the thigh failed to reveal atrophy, and the overlying skin was normal. Roentgenograms of the knee were essentially normal.

After three months of conservative therapy, an arthrotomy was performed through a lateral parapatellar incision. A blue cystlike mass was encountered in the capsule; this was dissected free and excised *in toto*. The pathologist's report was: "Benign hemangioma of knee joint, partially telangiectatic and partially cavernous in type." The articular structures were not disturbed by the process. The patient had a smooth postoperative course and was discharged from the Hospital one week after the arthrotomy. She received intensive physical therapy for approximately two weeks, and was discharged with almost complete restoration of knee motion. Two and one-half years after operation the patient reported normal function of the knee.

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DISCUSSION

Articular hemangiomata may be either juxta-articular or intra-articular. An intermediary type, which involves both the intra-articular and periarticular structures, may be added to the classification. In the juxta-articular type the process involves the periarticular structures, particularly the quadriceps muscle, and the tumor is always palpable. This type is characterized by the absence of involvement of the capsule and synovial membrane and, therefore, presents a clinical picture quite different from the intra-articular variety.

The intra-articular type is demonstrated by the two cases presented. The process may occupy any part of the synovial cavity, and the anterior fat pad may be completely replaced. The tumor is capable of causing destruction by pressure atrophy, and one case has been reported in which deep erosions in the cartilage and underlying bone were encountered. This presents a difficult problem in treatment.

Histologically, the articular hemangiomata have been classified as cavernous, capillary, and telangiectatic. Excessive fat tissue or small zones of chronic inflammatory reaction may be seen. These lesions are probably not true tumors, but rather hemartomata. They are congenital malformations of circumscribed vascular tissue, and, as such, show no capillary budding (Figs. 1-A and 1-B). The sections show a system of sinusoids in which the spaces are lined by endothelial cells. The remaining wall is made up of collaginous connective tissue. There is no evidence of thrombosis; this feature is of importance in considering diagnostic characteristics.

As mentioned previously, articular hemangiomata are usually not suspected before operation. The impressions most commonly mentioned are lesions of the menisci, loose bodies, or articular tumors, without specification of the type. In the first case presented, the initial impression was that of internal derangement, a second impression of synovitis being mentioned. In the second case the diagnosis was tumor, type undetermined.

FIG. 1-A

(S-40-46) Low-power magnification showing telangiectatic portion of hemangioma. The lumen is filled with blood; the walls, extremely thin, are composed of a single lining of endothelial cells and a very delicate, thin layer of connective tissue.

Clinically, the first symptom in these cases is pain, often appearing after trauma The trauma apparently causes hemorrhage from the hemangioma, either by direct con-

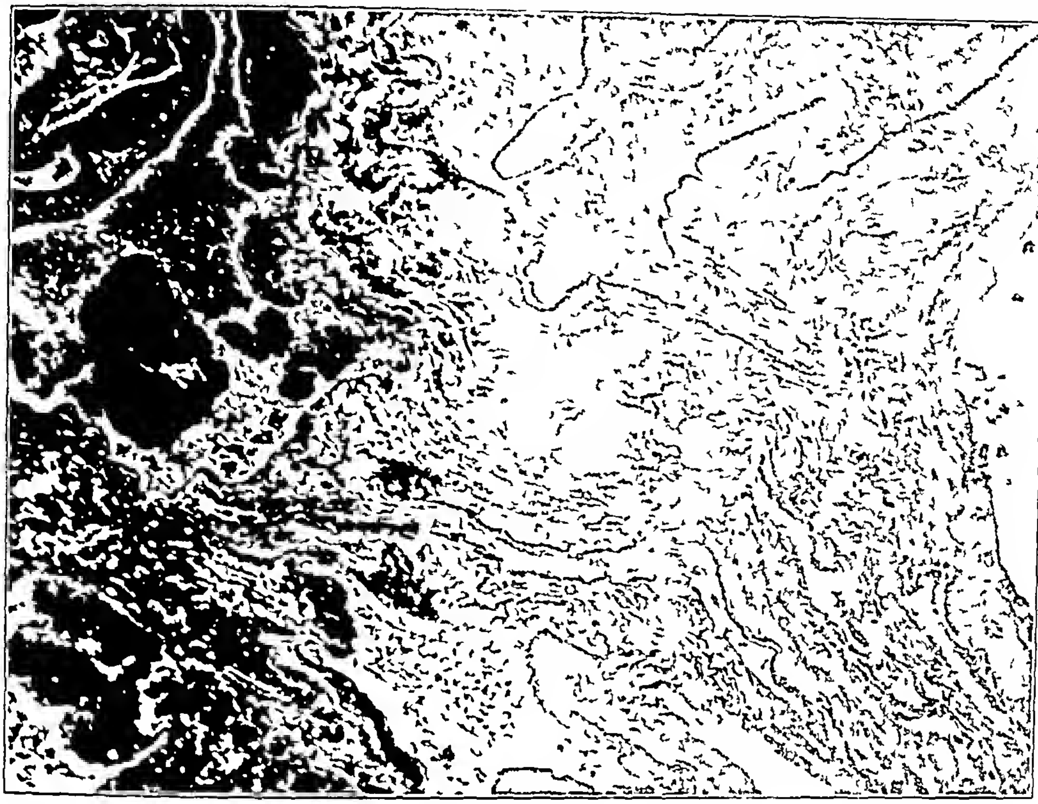

FIG 1-B
Cavernous portion of hemangioma with thick-walled sinusoids, most of them filled with blood

FIG 1-C
Shows portions of both cavernous and telangiectatic capillary hemangioma

FIG 2-A

(S-733-45) Capillary hemangioma, in low-power magnification

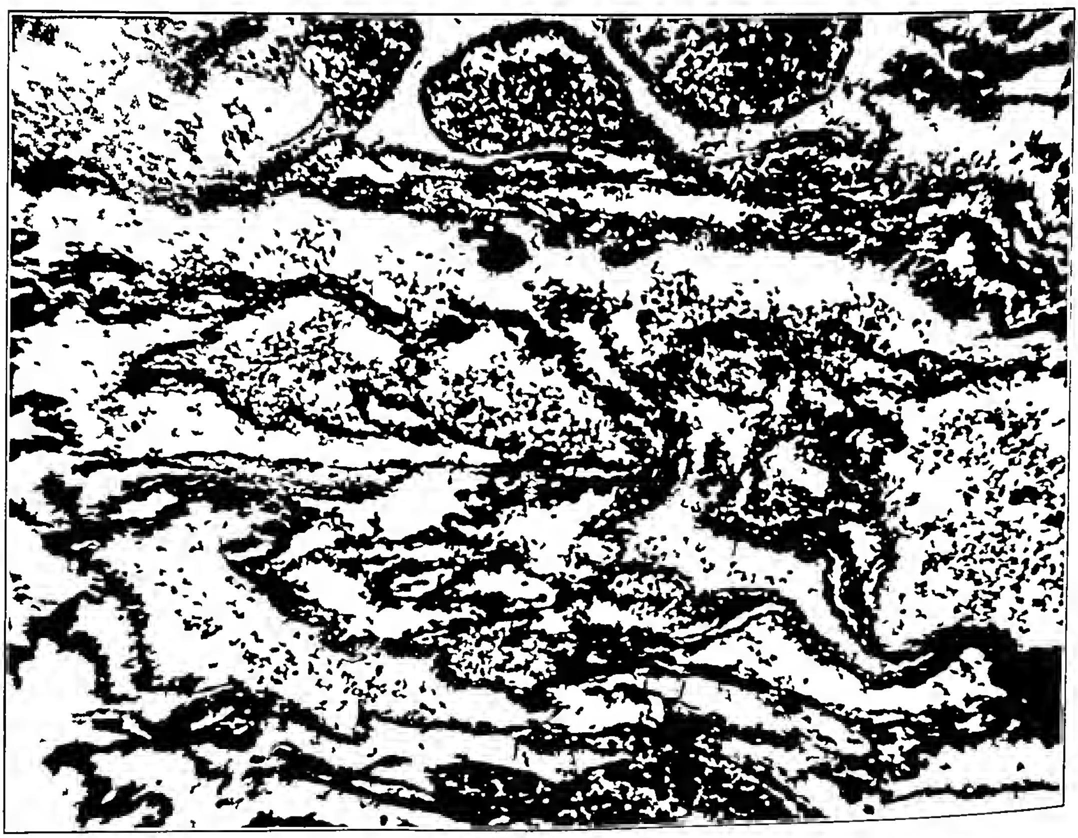

FIG 2-B

Capillary hemangioma, under high-power magnification, showing the distended capillaries and thin-walled sinusoids filled with blood

tusion or by pinching between the articular surfaces. Serous or serosanguineous effusions are frequently encountered in the course of these lesions, such a phenomenon being readily explained by the fragility of the vascular walls which make up the structure. Both pain and swelling may appear at long intervals, accompanied by partial loss of joint motion. Blocking and buckling, either alone or in combination, have not been observed. Atrophy or hypotonia of the muscles of the thigh may be seen. From these signs and symptoms it would obviously be difficult to arrive at a diagnosis of hemangioma. If hemarthrosis develops, two more possibilities are immediately suggested,—namely, hemophilia and hemorrhagic arthritis.

When cutaneous angioma coexists, articular involvement is strongly suggested. These masses of tissue do not show pulsation or rhythmic expansion; if this is observed, a diagnosis of cirsoid aneurysm should be made. These areas of tissue are very sensitive to pressure and even to mild palpation, thus accounting for the diagnosis of an inflammatory lesion in many cases.

The obvious deformity which accompanies most of the extra-articular hemangiomata is easily recognized. However, the intra-articular variety may develop within the joint cavity, have sufficient space in which to expand, and thus be overlooked on mere inspection. The volume changes which accompany changes in posture are of the utmost importance and, as one can appreciate from the histological picture, there is ample space for distention and collapse of these multiple sinusoids.

The differential diagnosis from hemarthrosis of hemophilia is established by the sex of the patient, the presence of increased coagulation time, and the clinical characteristics of hemophilic arthropathy, which leads to chronic arthritis with restriction of function and finally to ankylosis in flexion. The one condition in which a differential diagnosis may be virtually impossible is hemorrhagic arthritis. The histological appearance of diffuse hemorrhagic synovitis will serve to differentiate these two, yet the clinical appearance may be indistinguishable.

Loose bodies within the joint may also present a problem in differential diagnosis, for in either case the signs and symptoms are compatible with articular derangement.

The roentgenographic examination is rarely helpful in diagnosis but, as the first case demonstrates, it may be of slight benefit. It is possible to visualize articular angiomata by the use of an opaque material, injected intravenously. It is relatively easy to see the area infiltrated with such a contrast medium, but the shadow will often disappear in about fifteen minutes due to the rapid dilution of the substance in the blood current of the angioma.

Hemangiomata may disappear spontaneously as a result of thrombosis and subsequent scarring, but this cannot be relied upon, particularly about the knee, where repeated traumata are common. The only logical treatment of these lesions is that which is designed to eradicate the mass. Although there are many proponents of treatment with roentgen rays and radium, it seems more reasonable to assume that surgical extirpation is the treatment of choice. Surgery is often necessary to verify the diagnosis.

SUMMARY

Articular hemangiomata can be diagnosed prior to surgery in practically all cases, provided the correlation between the clinical picture and the pathological process is fully appreciated. These signs are significant: (1) the presence of a circumscribed mass, which is covered by normal skin and which increases in size when the extremity is in the dependent position; (2) the presence of blood after puncture of the mass; and (3) the disappearance of the contrast substance roentgenographically after injection into the vascular area. Surgical excision offers excellent end results.

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OSTEOSYNTHESIS OF THE NECK OF THE FEMUR *

BY JOHS SPOTOFT, M D, KALUNDBORG, DENMARK

So far, no comprehensive report has been made of the final results of extra-articular osteosynthesis, which was introduced with the Smith-Petersen nail We consider an observation period of three to four years as essential in order to get reliable impressions about the final results

The purpose of this work has been to elucidate the value of extra-articular osteosynthesis, the judgment being based upon an analysis of the case histories of a considerable number of patients, and correlation of these findings with a late examination of the survivors The patients were operated upon in twelve great Danish surgical clinics, prior to 1939 After an observation period of at least three and one-half years, all the survivors—a total of 183—have been re-examined clinically and, except in three cases, roentgenograms in two planes have been taken

CLASSIFICATION OF THE FRACTURE

For several reasons it is difficult to compare the various statistics concerning fracture of the femoral neck, not least because of the confusion prevailing as to the classification of the fracture As neither the anatomical classification, Bohler's classification (as valgus fracture and varus fracture), or Pauwels' classification (into three degrees, according to the angle between the fracture plane and the axis of the femur) gives a generally valid impression of a fracture of the neck, the author has found it practical to combine the three classifications This affords at once an anatomical, pathological, therapeutic, and prognostic impression

This combined classification is exceedingly simple, namely

1 True fracture of the femoral neck
   A Valgus fracture
   B Varus fracture, with consideration of the angle between the fracture plane and the axis of the femur
2 Pertrochanteric fracture

* Abstract of monograph written by author in 1944 (see reference) Presented with permission of Ejnar Munksgaard, Copenhagen

TABLE I

DISTRIBUTION OF FRACTURES

Fracture		No.	Per cent
True fracture of the femoral neck		329	64
Valgus fracture	51 (15.5%)		
Varus fracture	278 (84.5%)		
Pertrochanteric fracture		183	36
Total		512	100

In calculating Pauwels' angle it is practical to use roentgenograms taken during the operation where the femur is in slight inward rotation, as the angle in question is real only in this position. It cannot be calculated, for instance, on roentgenograms of recent unreduced varus fractures.

From 1931 until 1938 a total of 512 patients with fracture of the neck of the femur were admitted to four surgical departments in Copenhagen. An analysis of all the roentgenograms of these patients, according to the classification set forth, gave the distribution shown in Table I. Therefore, it is safe to say that, of all the fractures in this region, two-thirds are fractures of the neck itself (about one-sixth of these are valgus fractures, while about five-sixths are varus fractures) and one-third are pertrochanteric fractures.

HEALING OF FRACTURE OF THE FEMORAL NECK

Today it is the general view that every fracture of the femoral neck which is reduced ideally and retained in this position for a sufficient length of time will heal by osseous union. In explanation of the poor healing capacity of the neck of the femur, the following causes have been mentioned.

Poor Nutrition of the Head and Neck

The blood supply of the head and neck is subject to wide variation, and undoubtedly the apparently capricious appearance of capital necrosis and delayed healing is in part due to this. The synovial vessels are liable to damage because of the injury to the capsule, and of course this risk increases with the dislocation. Owing to the outward rotation, the vessels of the posterior aspect of the neck have a better chance of remaining unbroken. Even though the vessels are not ruptured by the dislocation, however, they may be stretched, twisted, or compressed so that the blood flow becomes compromised.

It is reasonable to assume, then, that a preliminary reduction of the fracture, as soon after the accident as possible, is essential in order to protect these vessels from further injury. Consequently, the usual confinement of the patient to bed for several days before reduction is inexpedient.

TABLE II

RELATION BETWEEN DEGREE OF DISLOCATION, HEALING, AND NECROSIS OF THE HEAD

Primary Dislocation	No. of Patients	Healing		Capital Necrosis	
		(No.)	(Per cent)	(No.)	(Per cent)
Marked	78	54	69.2	52	66.7
Slight	100	86	86.0	33	33.3

TABLE III

RELATION BETWEEN NECROSIS OF THE HEAD AND HEALING IN 180 PATIENTS

Degree of Necrosis	No. of Patients	Healing (No.)	Healing (Per cent)	Pseudarthrosis (No.)	Pseudarthrosis (Per cent)
Total	59	41	69.5	18	30.5
Partial	26	23	88.5	3	11.5
None	95	84	88.4	11	11.6

TABLE IV

RELATION BETWEEN AGE OF THE PATIENT AND HEALING OF THE FRACTURE

Age of Patients Re-examined	No. of Patients	Healing (No.)	Healing (Per cent)
Under 60 years	77	61	79.2
60 years and over	103	80	77.7

That the dislocation and the resulting decrease in nutrition of the head play a considerable role in this respect is evident from the findings in Table II, in which the patients are classified according to the degree of primary dislocation. It will be noticed that the greater the primary dislocation, the greater is the probability of capital necrosis.

Necrosis of the Head

The relation of this phenomenon to the process of healing will be discussed later. Necrosis forms no absolute obstacle to healing, merely delay. Table III illustrates the relation between capital necrosis and healing in 180 patients who were re-examined.

Age of the Patient

Previously, clinicians believed that the age of the patient played an important role in healing. This is not indicated by the present study (Table IV). Age in itself should not be looked upon as a contra-indication for operative treatment.

Of those factors under our control which promote healing of the fracture, only the following are important: quick and gentle reduction in order to avoid additional vascular injuries,—above all, an ideal reduction and a sufficiently long immobilization.

Pauwels' Theories

Fuchsig analyzed forty-one fractures treated by the Whitman method, and his findings coincide with Pauwels' theories. Thus he concluded that eleven of fifteen pseudarthroses belonged to fractures in Pauwels' third-degree class. Opinions differ as to the patients submitted to osteosynthesis. Most investigators, however, find no concordance between the angle of the fracture and osseous healing.

TABLE V

HEALING OF THE FRACTURE IN RELATION TO PAUWELS' CLASSIFICATION

Pauwels' Classification of Fractures	No. of Patients	Healing (No.)	Healing (Per cent)
First degree	22	18	81.8
Second degree	110	85	77.3
Third degree	46	37	80.4

The present material has been analyzed with a view to Pauwels' theories. The relation between Pauwels' three groups and the osseous healing in 178 patients is presented in Table V. The healing percentage is about the same for all three groups.

With a special apparatus belonging to the Danish State Testing Laboratory, the author has tried to see whether Pauwels' theories might be confirmed experimentally. In specimens obtained from postmortem material, fractures of the first and third degree were produced, respectively, on the right and left sides of the neck of the femur, after which the fracture fragments were nailed. In the apparatus a weight of 250 kilograms was put on the head, alternating with complete "unloading" (thirty times per minute), corresponding to a slow gait *in vivo*. In all cases the results were consistent, showing that in both forms the fracture site was able to withstand a 10,000-repetition periodic tolerance test with a load of 250 kilograms. With an additional load, the third-degree fractures broke down earlier than the first-degree fractures,—at 330 and 190 kilograms, respectively.

This illustrates the enormous fixation power of the nail, even under mechanically poor conditions. *The outcome of the experiments lends support to Pauwels' theories.*

Duration of the Healing Process

The period required for healing has been estimated differently by various authors—from two or three months to two or three years—and there can hardly be any doubt that it is subject to wide variation. Furthermore, the estimate is based upon roentgenographic evidence, which is very difficult to judge in this fracture because the periosteal callus is lacking.

A critical review of the roentgenograms presented in various books and papers as demonstrating osseous healing reveals that in many cases this healing is questionable. Many surgeons have suffered disappointment when, trusting the roentgenographic diagnosis of osseous healing, they have extracted the nail and then obtained a fresh dislocation of the fracture.

It is advisable, therefore, to follow the criterion given by Felsenreich. Osseous healing is reliable only when the roentgenogram clearly shows osseous trajectories crossing the fracture gap everywhere and filling it completely.

PLACING OF THE NAIL

In deciding where to place the nail in the neck and head of the femur, two factors should be taken into consideration: (1) the optimum biological conditions for healing and (2) the mechanical aspects of the fracture. The nail has to be placed where it will best meet the requirements of both factors.

From a biological point of view, the question is how to induce the best healing conditions possible. According to Pauwels, these are obtained by elimination of dislocating forces and by the production of functional pressure at the site of the fracture.

From a mechanical point of view, attention must be paid to the following three points:

1. *Firmness of the Cervical and Capital Spongiosa in Various Sections.* Nystrom found the firmness of the cervical spongiosa to be greatest postero-inferiorly, while in the head it was greatest in the center. The trochanteric cortex is also strongest posteriorly, where it is reinforced by the osseous trabeculae from the lesser trochanter. It will, therefore, seem most proper to place the nail steeply, a little posteriorly in the neck, and centrally in the head.

2. *Dislocating Power of the Muscles.* It is well known that the outward rotators of the hip joint are very powerful. Subsequently it will be described how this force contributes to redislocation under rotatory cutting by the nail in the head. The more the nail is placed above and anteriorly in the head, the more readily will this complication appear. Therefore, if regard is to be paid to this displacing influence of the muscles, the nail ought to be placed a little inferiorly and posteriorly in the head.

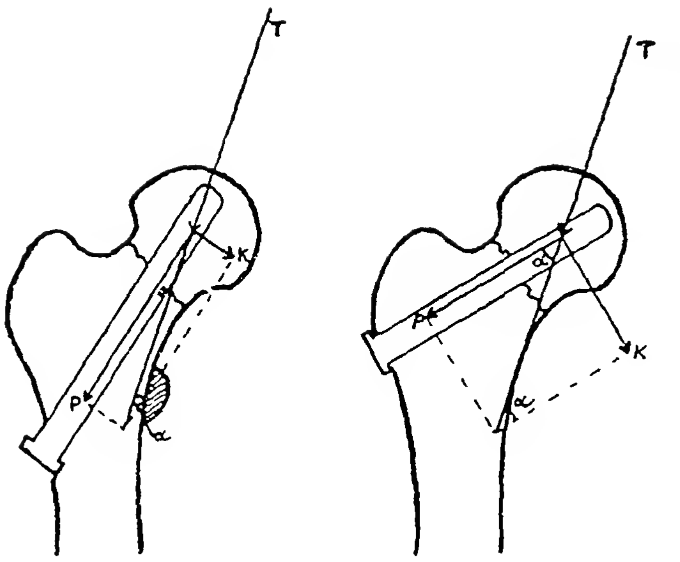

FIG 1

A comparison of the distribution of forces on the fracture and the nail when the placement of the nail is steep and when it is more horizontal

3 *Dislocating Forces Arising from the Weight of the Body during Walking* The forces produced by the weight of the body in walking are stronger than is generally imagined From the fundamental work on the gait of man, reported by Fischer in 1899, it is evident that, every time the foot is put to the ground during ordinary walking, the head of the femur has to carry a load about four or five times the weight of the body Knowledge of the enormous forces acting on the head of the femur during walking tends *a priori* to make one hesitate in allowing a patient to bear weight on a limb soon after osteosynthesis has been performed

Figure 1 illustrates the mutual relations of the forces with a steep placement of the nail and with the prevailing, more horizontal placement The force, *T*, that acts on the head of the femur may be divided into *P*, which is parallel with the nail and has an impacting effect on the fracture, giving a functional pressure at the fracture site, and *K*, which acts vertically on the nail It will be noticed that K=T sine *α* This means that the steeper the position of the nail, the more functional will be the pressure on the fracture site, and the less the bending force acting upon the nail With the two angles of the nail demonstrated (Fig 1)—namely, 140 degrees and 115 degrees with the longitudinal axis of the femur—the difference is so great that the nail placed steeply is able to carry nearly twice as great a weight as is the nail in a more horizontal position

In addition, owing to friction, the steeply placed nail offers greater resistance to the displacing forces acting on the site of the fracture Finally, when the nail is placed steeply and the bending force on it thus is reduced, the risk of the nail cutting into the head is lowered

Thus the steeply placed nail offers the following advantages

1 *The displacing forces at the site of the fracture are diminished*

2 *The nail is exposed to less strain as a result of movement and walking, and hence it does not bend or break so readily*

3 *Spontaneous impaction is promoted,—primarily by diastasis at the site of the fracture, secondarily by absorption of the neck*

4 *The functional (callus-inducing) pressure on the fracture surface is increased*

5 *The risk of the nail cutting into the head is reduced*

In contrast to these advantages, only one objection can be made It is more difficult to drive the nail vertically than horizontally This, however, is merely a question of technique With preliminary drilling before the introduction of the wire, as well as before the driving in of the nail, there is no difficulty in placing the wire and nail in a steep position

Experiments on the Significance of Placement of the Nail

In the State Testing Laboratory at Copenhagen, the author has carried out a number of experiments on femora with recent or old fractures of the neck, removed at autopsy and on femora of patients who died from other causes Attempts were made to answer two questions

TABLE VI

FREQUENCY OF NECROSIS OF THE HEAD

Patients Re-examined	No. of Patients	Total Necrosis of Head (No.)	Total Necrosis of Head (Per cent)	Partial Necrosis of Head (No.)	Partial Necrosis of Head (Per cent)
Total number	180	59	32.8	26	14.4
With osseous healing	141	36	25.5	22	15.6

TABLE VII

RELATION BETWEEN PRIMARY DISLOCATION AND NECROSIS OF THE HEAD

Primary Dislocation	No. of Patients	Necrosis of Head (No.)	Necrosis of Head (Per cent)
Slight	100	33	33.3
Marked	78	52	66.7

1. Are nailed fractures suitable for early weight-bearing? In particular, does the asserted difference in the weight-bearing capacity in Pauwels' three groups hold true?

2. Which placement of the nail is ideal from an entirely mechanical point of view?

The outcome of the first series of experiments has been noted, and the experimental technique has been mentioned briefly. Most of the experiments were carried out as follows. First, weight was applied to the bone directly with increases of 20 kilograms, up to 240 kilograms; then the experiment was continued with a weight of 250 kilograms, thirty times a minute. If the bone did not give way, this weight was continued for a total of 50,000 repetitions, corresponding to a walk of about ten miles. After this, the addition of weights was continued with increasing pressure until the bone broke down, at the site of the fracture or elsewhere. All experiments were carried out in duplicate, and both femora were removed in every instance so that one acted as control.

The question as to whether the site of an osteosynthesis is suitable for early weight-bearing is very difficult to settle. Numerous clinical experiences have shown plainly that early weight-bearing may give excellent results with osseous healing. Many of the experiments showed also that the "nailed" bones were able to withstand protracted periodic weights of 250 kilograms without any shifting at the site of the fracture. The outcome of these experiments, however, was largely dependent upon the quality of the osteosynthesis.

The difference between the first and the third-degree fractures mentioned by Pauwels was confirmed by these experiments. Depending upon the strength of the bone, the breakdown appeared when weights of 100 to 450 kilograms were added. In all the experiments, however, the first-degree fractures did not break down until the weight was about one and one-half times that under which the third-degree fractures broke down.

Of greater interest are the experiments with Pauwels' third-degree fractures, when the nail is first placed almost horizontally and then more steeply. In eighteen duplicate experiments, the results were all in favor of the steep placement of the nail. A typical example of such an experiment is given.

Both bones were able to withstand 50,000 applications of 250 kilograms of weight without any change in form, but with an impaction which in both cases amounted to 3.5 millimeters. Under subsequent weight additions with increasing pressure, the bone in which the nail had been placed steeply broke down at a pressure of 730 kilograms, whereas with the more horizontal placement of the nail, the bone broke down at 340 kilograms.

In recapitulating the evidence provided by theoretical considerations, clinical experiences, and practical experiments in proper placement of the nail, the following points should be emphasized.

TABLE VIII

RELATION BETWEEN NECROSIS OF THE HEAD AND AGE OF THE PATIENT

	Under 50 Years	51–60 Years	61–70 Years	Over 70 Years
Number of patients	28	33	53	27
Necrosis of head	12 (42.9%)	13 (39.4%)	24 (45.3%)	9 (33.3%)

TABLE IX

ROENTGENOGRAPHIC RE-EXAMINATION OF 180 PATIENTS

Group	No. of Patients	Per cent
Healing of the fracture	148	82.2
Pseudarthrosis	32	17.8

1. Subcapital and transcervical fractures should be analyzed according to Pauwels' principles of classification.

2. In first and second-degree fractures, central placement of the nail in the neck and the head is excellent, even though placing of the nail more steeply is better mechanically.

3. In third-degree fractures, the nail ought to be placed steeply, preferably at an angle with the femoral axis of at least 150 degrees.

4. In the horizontal plane the nail should be placed centrally or a little posteriorly in the neck, if the reposition permits. One has to avoid having the nail enter the anterior upper quadrant of the head, because this placement disposes to redislocation through cutting by the nail during rotation.

CAPITAL NECROSIS

In the fractures in the present study—all treated by osteosynthesis—the most frequent late complication has been necrosis of the head of the femur followed by arthrosis, and this is the commonest cause of permanent disablement. In the literature, capital necrosis is not fully dealt with, simply because of its late clinical manifestation, so that the re-examinations reported imply too short a period of observation.

The present material, with an observation period of at least three and one-half years, shows the surprising fact that, among 180 patients who were re-examined roentgenographically, total necrosis of the head was found in about one-third and partial necrosis in nearly one-sixth. Thus the outcome was complicated by capital necrosis in nearly half of the patients (Table VI).

Etiology

Most authors agree that necrosis of the head of the femur belongs to the large group of cases of aseptic bone necrosis of vascular nature. In general, we may expect the extent of capital necrosis to be parallel with the injury to the capsule (Table VII). Among patients with little or no primary dislocation, capital necrosis was found in about one-third, whereas in those with marked primary dislocation, it was found in about two-thirds.

Site and Form of the Fracture

In contrast to what has been asserted by many authors, the site of the fracture plays a minor role in the development of capital necrosis. Among the healed subcapital and transcervical fractures in the present study, capital necrosis has been demonstrated respectively, in 42.6 per cent (twenty-three of fifty-four) and in 40.2 per cent (thirty-five of eighty-seven).

TABLE X

OUTCOME OF CLINICAL RE-EXAMINATION OF 183 PATIENTS

Group	No. of Patients	Per cent
I. Ideal	50	27.3
II. Good	42	23.0
III. Fair	52	28.4
IV. Poor	39	21.3

Neither does the form of the fracture appear to play any role in this connection. Among the healed fractures of Pauwels' first and second degrees (taken as one group) and those of third degree, capital necrosis had developed, respectively, in 41.7 per cent (forty-three of 103) and in 40.5 per cent (fifteen of thirty-seven). Therefore, we may hardly expect any relation between the form and site of the fracture and capital necrosis.

Age of the Patient

Various authors think that capital necrosis is particularly frequent in young persons, probably because the complication gives more conspicuous symptoms in youth. That its frequency probably does not increase with increasing age is evident from Table VIII, in which only healed fractures are reported.

Valgus Position of the Head

There is no foundation for the belief, expressed by Pauwels, that the valgus position is nearly always associated with capital necrosis, owing to the resulting change in the load placed on the head. Among the healed fractures in this study in which the head was in marked valgus position and those in which the head was in nearly normal position, capital necrosis had developed, respectively, in 38.5 per cent (fifteen of thirty-nine) and in 40 per cent (sixteen of forty). It is the more fortunate as, to obtain good statics, the valgus position ought to be aimed at during the operation.

Poor Reposition

Felsenreich and Mouchet have emphasized that poor reposition disposes to capital necrosis. In the present study, the figures to this effect are too small to convey any idea about the question. No doubt the fractures associated with marked dislocation are generally accompanied by an extensive tear of the capsule, and for this reason alone they predispose to capital necrosis.

The Nail as a Foreign Body

Before osteosynthesis was adopted, capital necrosis was by no means an unknown phenomenon or particularly rare. Indeed, most authors think that capital necrosis is not due to the presence of the nail as a foreign body, although several believe that the nail, with its broad flanges, tends to compromise the nutrition of the head.

Nystrom called attention to the risk involved when the tip of the nail is placed either too near the fovea capitis or in it. In order to get an idea of the risk involved by such placing of the nail, the material has been analyzed with this point in view. Among the fractures in which the tip of the nail was in or near the fovea capitis and those in which the tip was at least 0.5 centimeter from it, capital necrosis appeared, respectively, in 56.4 per cent (twenty-two of thirty-nine) and in 35.3 per cent (thirty-six of 102). Even though the figures furnish no conclusive proof, they indicate that the vicinity of the fovea should be avoided during operation.

The Metal

Several authors hold that the metal plays an important part in the appearance of capital necrosis. I think it depends largely upon the character of the steel, but in this study capital necrosis is nearly three times more frequent in cases with roentgenographic evidence of nail osteitis as in cases without nail osteitis (respectively, thirty-five of seventy-nine and six of thirty-six). Therefore, the physician must be very careful in his choice of nail material. To be on the safe side, he should use V2A steel or Vitallium.

From the deliberations concerning the etiology of capital necrosis, the conclusion must be drawn that avascularity of the head is the most important factor. There are probably only two other contributory factors,—poor nail material and poor placement of the nail.

Diagnosis

Once the subjective symptoms of pain, limp, and limitation of motion have appeared, it is easy to make the diagnosis. Roentgenograms show spotted configuration in the head and, often at this stage, infraction and possibly beginning arthrosis.

Treatment

Since capital necrosis begins with softening of the head from about the fifth month to the commencement of the third year, the only rational treatment is to free the extremity from too much strain until the head again has become firm. In 1930, Phemister showed that infraction may be avoided by elimination of weight-bearing for a sufficient length of time.

In determining the thoroughness of this sparing of the hip, it is reasonable to take into account the age of the patient, his weight, mental habitus, and social status. In most cases it will be sufficient to employ merely one cane, if it is used effectively, to spare the hip a great deal of strain. Complete elimination of weight-bearing is a severe trial, mentally as well as physically, in old and feeble persons; in dealing with younger persons, it is only rational to make the demand more categorical, considering that such a "quarantine" for a year and a half probably will save them from permanent disablement.

In the present study it has been found that, in capital necrosis without avoidance of weight-bearing, the chance of infraction is 75 per cent. If infraction has taken place, the prospect of a satisfactory result is only 15 per cent.; in capital necrosis without infraction the percentage is about 70.

RESULTS

Roentgenographic Results

It is difficult to judge healing from a roentgenogram, and the surgeon has to be very critical to avoid erroneous conclusions that may have disastrous consequences. In order to designate the condition as unquestionable osseous healing, the entire fracture line should be crossed by trajectories from the neck into the head, without any zone of condensation

TABLE XI

Estimation of Functional Results in Relation to Healing and Necrosis of the Head

Group	No. of Patients	Healing (No.)	Healing (Per cent)	Necrosis of Head (No.)	Necrosis of Head (Per cent)	Arthrosis (No.)	Arthrosis (Per cent)	Necrosis of Head plus Infraction (No.)	Necrosis of Head plus Infraction (Per cent)
I	50	50	100	0	0	3	6	0	0
II	41	40	97.6	17	41.5	21	51.2	6	14.6
III	51	36	70.6	37	72.5	39	76.5	30	58.8
IV	38	22	57.9	31	81.6	29	76.3	25	65.8

In Table IX is recorded the outcome of the roentgenographic re-examination of 180 patients. Healing was obtained in over 80 per cent., which may be considered a fairly good result. However, with increasing experience in the performance of these operations, more frequent postoperative control examinations, and more reoperations, it should be practicable to obtain a percentage of healing of nearly 100.

Functional Results

The functional results may be divided into four groups (Table X).

Group I. Ideal Results. The patient has no complaint, and the function of the hip is as good as before the accident.

Group II. Good Results. The patient has only slight inconvenience,—at the most, some "rheumatism" or rapidity of fatigue when a heavy weight is put on the hip. The walking capacity is about the same as prior to the accident. The physical examination may reveal a reduction in mobility of less than 10 degrees in each direction.

Group III. Fair Results. The patient complains of reduced mobility in the hip and a lowered working capacity. Pain is frequent; dressing is difficult. The physical examination shows some shortening and a considerable reduction in mobility. In some cases a moderate contracture may be ascertained.

Group IV. Poor Results. The walking capacity is greatly impaired or completely abolished. The patient's working capacity is approximately zero. Intense pain is present in the hip. The physical examination shows marked reduction in mobility, and at times pronounced contracture or even ankylosis.

Groups I and II correspond to what are designated in most other statistical studies as "good results".

One may wonder that the results are not better than as presented here. If the primary results had been estimated and recorded, no doubt they would have been far better, but it is the late clinical symptoms in cases with capital necrosis that put their stamp on the material. As previously mentioned, these late symptoms do not manifest themselves until about a year and a half after the accident.

In Group I (Table XI) all the fractures have healed and there is no capital necrosis, but three patients show roentgenographically a slight arthrosis that gives no symptoms. It is also evident that pseudarthrosis and capital necrosis with infraction and arthrosis are the cause of the poor functional results.

It would be interesting to compare the results of the Whitman treatment and osteosynthesis, but it is impracticable to obtain any reliable basis for such a comparison, because no fairly large study of Whitman-treated patients has been reported with a sufficiently long period of observation.

Furthermore, it must be emphasized that the material presented in this work comes from twelve different surgical departments and represents the first experiments with an operative method, which is well characterized by Mouchet in the following words: *En fait, il n'y a pas de procedé simple.*

POSTSCRIPT

The author has been able to present a group of patients treated according to the principles described herein. (Most of the patients were operated upon, and the after-treatment was given by the author.) This report covers all the patients who, during the period from 1941 to 1943, were given operative treatment for fracture of the neck of the femur in the Odense County Hospital,—a total of sixty-eight. Of this total, six died in the Hospital after the operation, and twelve died after discharge from the Hospital. The remaining fifty patients have all been re-examined clinically and roentgenographically after an observation period of at least three and one-half years, just as was done in the

TABLE XII

ROENTGENOGRAPHIC AND FUNCTIONAL RESULTS IN THE TWO GROUPS

Results	Old Material (180 Patients) (No)	Old Material (180 Patients) (Per cent)	New Material (50 Patients) (No)	New Material (50 Patients) (Per cent)
Healing	148	82 2	47	94
Pseudarthrosis	32	17 8	3	6
Necrosis of the head	85	47 2	8	16
Ideal	50	27 7	39	78
Good	42	23 3	2	4
Fair	52	28 8	4	8
Bad	39	21 7	5	10

preceding study Thus, the two groups of patients are similar and have been treat exactly alike, so that they are comparable in every respect

The roentgenographic and functional results in the two groups are recorded i Table XII After treatment of the patients according to the principles mentioned, tl percentage of healing increased from 82 to 94, while the frequency of capital necros decreased from 47 per cent to 16 per cent,— that is, to one-third of the former frequenc This is reflected in the functional results, as in the second group 82 per cent of the patien are found in the good class (Groups I and II) as contrasted with 50 per cent of those i the previous study

With our present knowledge concerning fracture of the neck of the femur and necros of the head, we may hardly expect to obtain better therapeutic results Capital necros with subsequent arthrosis still threatens the late functional results in one of every si patients

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THE USE OF THE TECHNIQUE OF PROGRESSIVE-RESISTANCE EXERCISE IN ADOLESCENCE *

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In adolescence, such disorders as mechanical derangement of the knee joint, low-back strain, and insufficient development of the arms, shoulders, and chest frequently occur, and suggest the use of therapeutic exercise. Recently a technique has been reported[2,3,16] for the development of muscle power, which gives promise of being of considerable value. The basic principle of this technique, progressive-resistance exercise, is that muscle power is better developed by exercising a muscle a few times at its maximum capacity than by having the muscle repeat an exercise many times against less resistance. Special equipment and methods have been developed to permit the proper application of this principle[2,3].

The technique of progressive-resistance exercise has important implications beyond the strictly clinical field for those who deal with adolescents. It relates to that philosophy which in recent years has emphasized the abuse of rest[11,14] and the need for the development of fitness rather than the avoidance of strain and fatigue[6], and takes issue with those physical educators who emphasize the social-psychological objectives of athletics and neglect the development of adequate muscle power and endurance[8]. It is obvious to most of us who deal with adolescents that strength needs to be developed as well as endurance, coordination, flexibility, and skill, and that, if injuries are to be avoided, some games[5] demand considerable strength about the joints. In addition, it is undoubtedly true that most activities will be performed more successfully and with less fatigue when greater strength and endurance are present; the individual will pay less physiologically, and therefore become less fatigued, when he is able to react well below his maximum limit.

This clinical report discusses the use of the technique of progressive-resistance exercise in the after-care of knee injuries and low-back strains and in the muscle development of the arms, shoulder girdle, and chest in adolescents. None of these will be discussed in detail here; it is the purpose of this report only to indicate the apparent usefulness of this technique in the care of these common conditions, and to suggest its value as an addition to other types of physical therapy.

KNEE INJURIES

The tendency of knee injuries to recur is well known, and the need for combating the atrophy and hypotonia of the extensor muscles of the thigh which accompany these injuries is all-important[13,15]. Whether or not the ligaments are torn, whether the cartilage is damaged or removed, the most important part of the after-care of knee injuries is the development of strength in the quadriceps; frequently too much attention is paid to the lesion in the joint and too little to the subsequent development of power in the supporting muscles. Such exercises as quadriceps-setting, straight-leg raising, and walking are valuable in the early after-care of knee injuries and will gradually improve the power of the quadriceps; however, to prevent a recurrence of injury, it seems logical to us to strive for more than a return to former strength. Progressive-resistance exercises can restore the power lost, and can produce a much greater strength in the supporting muscles than they possessed prior to the initial injury. However, we do not feel that a knee joint

* This study was aided by a grant from The Grant Foundation, Inc.

which is free from fluid, has a normal range of motion, shows no atrophy of the thigh muscles, and can be vigorously extended against the examiner's resisting hand is necessarily ready for skiing, football, or other strenuous activities. These activities can, and do, put sudden and severe strain on the supporting muscles, far beyond the limits imposed at an examination. A knee joint is not ready for such stresses until it has extraordinary strength; absence of pathological signs is not enough.

Table I presents data concerning adolescents who were given progressive-resistance exercises for knee injuries. Twenty-five boys, ranging in age from thirteen to nineteen years, were treated. Two of them had previously had operations for the removal of a meniscus, one had considerable atrophy of the quadriceps following a dislocation of the patella, and the others had previously had tears of the collateral ligaments of varying severity. Careful clinical examinations were made and roentgenograms were taken before this type of physical therapy was begun. Those whose injury had been relatively recent were given a conventional course of heat and massage, patella-setting, and straight-leg raising exercises before progressive-resistance exercises were started. In several cases, thigh-circumference measurements were made, and in every case quantitative estimates of the quadriceps strength were obtained by determining the maximum weight which the quadriceps had the power to raise to the horizontal (full extension).

At the first exercise period the maximum number of pounds which could be raised to the horizontal (Figs. 1-A and 1-B) was determined, as was also the maximum amount which could be extended by the patient when seated in the hip-knee extension exerciser (Figs. 2-A and 2-B). One is rarely able to obtain accurate maximum values at the first testing period. Much more valid data can be obtained at the beginning of the second week, and for that reason we have used data obtained at this second testing period as representing the patient's maximum power at the beginning of the therapeutic period. Each individual's prescription was determined on the basis of the maximum load he had the power to raise, or extend, ten times. If he was capable of raising no more than twenty pounds attached to the boot, he would be asked to raise ten pounds ten times, fifteen pounds ten times, and twenty pounds ten times on each day, four days a week. At the beginning of each subsequent week the patient's maximum power was again determined.

FIG. 1-A

FIG. 1-B

Load-resisting knee-extension exercise.

FIG. 2-A

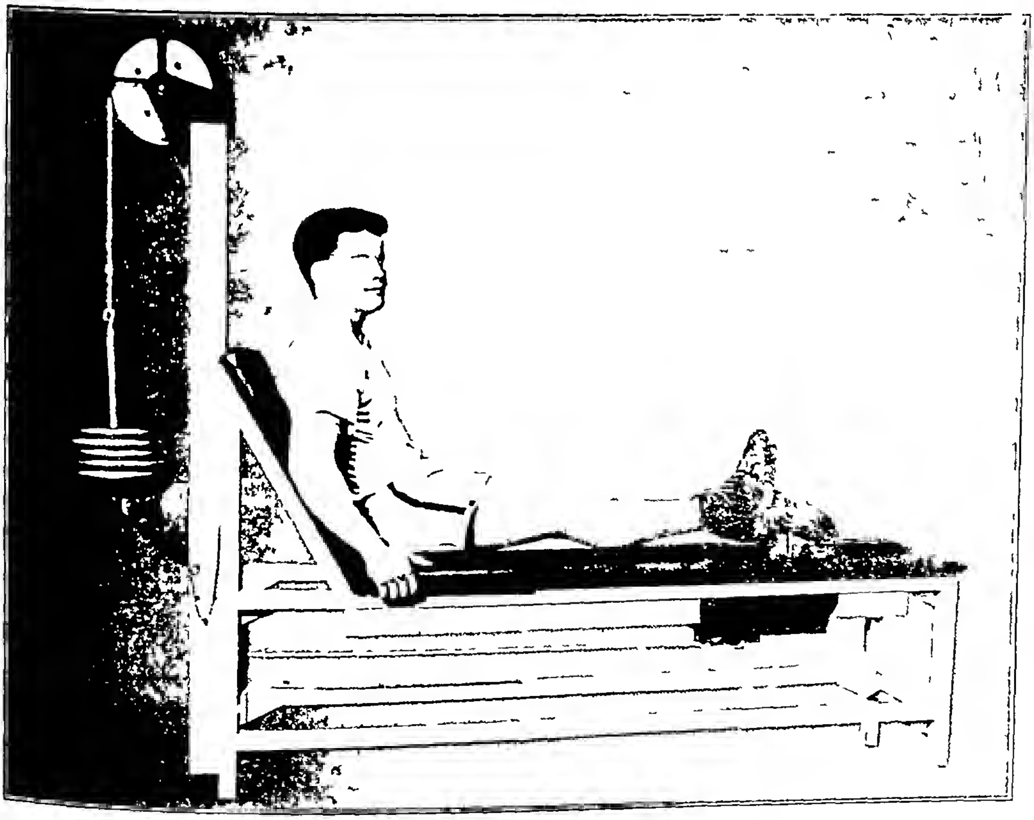

FIG. 2-B

Hip and knee flexion-extension exercise

TABLE I

PROGRESSIVE-RESISTANCE LOW-REPETITION EXERCISE FOLLOWING KNEE INJURIES IN TWENTY-FIVE BOYS

Patient	Age	Height (*Inches*)	Weight (*Pounds*)	Diagnosis	Approximate Time from Injury to Start of Exercise Program	Maximum Power at Start of Second Week		Total No of Exercise Periods	Maximum Power at Final Week		Interval between End of Treatment and Re-examination (*Months*)	Maximum Power at Re-examination	
						Hip-Knee Flexion-Extension (*Pounds*)	Knee Extension (*Pounds*)		Hip-Knee Flexion-Extension (*Pounds*)	Knee Extension (*Pounds*)		Hip-Knee Flexion-Extension (*Pounds*)	Knee Extension (*Pounds*)
H A	13	66	120	Collateral-ligament strain	2 years	50	27½	32	90	60	6	90	60
R B	16	72	155	Collateral-ligament strain	18 months	90	50	20	125	80	12	125	80
P Br	15	67	154	Collateral-ligament strain	4 weeks	65	40	40	130	80			
D B	16	66	109	Collateral-ligament strain	3 weeks	45	25	50	120	65	8	120	70
D C	17	72	177	Collateral-ligament strain and meniscus injury	6 weeks	70	50	20	110	65	2	110	80
S C	15	69	189	Collateral-ligament strain	2 weeks	110	50	24	130	80	9	125	85
I C	14	65	99	Collateral-ligament strain	6 weeks	30	12½	28	80	50	12	80	50
H C	15	69	149	Collateral-ligament strain	12 months	65	40	36	105	65	9	125	65
F D	16	69	155	Collateral-ligament strain	6 weeks	75	40	30	120	75	12	120	75
I L	19	69	152	Meniscectomy (postoperative)	4 months after operation	60	30	24	100	75	6	100	70

TABLE I (Continued)

P E	15	69	173	Collateral-ligament strain	6 months	—	15	36	—	90	9	—	95
J F	16	69	122	Collateral-ligament strain	18 months	60	30	21	105	70	5	110	75
K G	17	65	160	Collateral-ligament strain	3 weeks	70	22½	21	120	65			
A G	16	72	144	Collateral-ligament strain	1 year	35	5	10	90	70	9	100	70
R H	16	68	143	Collateral-ligament strain	6 months	85	35	18	125	70	10	125	70
H J	15	72	163	Collateral-ligament strain	1 month	80	60	31	110	75	6	125	65
K L	17	67	129	Collateral-ligament strain	4 years	65	30	20	100	70	5	100	80
J O	18	68	172	Collateral-ligament strain	4 weeks	90		28	120				
N P	17	70	180	Collateral-ligament strain	6 weeks	10	30	36	115	95			
T R	18	71	176	Collateral-ligament strain	4 weeks	80	35	28	120	65	10		70
K S	16	72	138	Dislocation of patella	8 weeks	10	25	11	105	65	4	105	60
G K	17	70	183	Collateral-ligament strain	6 months	75	30	24	110	65			
W P	17	70	169	Collateral-ligament strain	6 months	95	35	24	150	75			
L S	17	70	163	Collateral-ligament strain	8 months	60	20	24	110	55			
A W	18	68	165	Meniscectomy (postoperative)	5 years after operation	85	45	20	130	85			

TABLE II

WEEKLY PRESCRIPTIONS IN CASE H A

Week	Pounds of Resistance in Load-Resisting Knee-Extension Exercise (10 Repetitions Each)			Pounds of Resistance in Hip and Knee Extension-Flexion Exercise (10 Repetitions Each)		
First	15	20	25	35	40	[illegible]
Second	22½	25	27½	40	45	[illegible]
Third	25	30	35	45	50	[illegible]
Fourth	30	35	40	55	60	[illegible]
Fifth	40	45	50	65	70	[illegible]
Sixth	45	50	55	70	75	[illegible]
Seventh	50	55	57½	75	80	[illegible]
Eighth	50	55	60	80	85	[illegible]

and his prescription was properly increased (Table II) The exercises were continued until the strength reached was greater than that of the contralateral limb, and beyond which we judged little progress could be made within a reasonable time

It is clear from Table I that each of these boys became able to handle greatly increased amounts of weight within a relatively short period In seventeen cases we have had an opportunity to determine whether the ability to handle this much weight would gradually be lost after the treatment stopped The check-up intervals varied from two to twelve months In no instance was there any indication that the gains made in the therapeutic-exercise period had been lost, although none of these boys had done any exercise of this nature during those intervals Their retention of the gains made seems the more surprising because of the relatively high levels they had achieved

Brief comments about a few of these cases may clarify the type of condition which apparently benefited by this method, and illustrate a few points which have occurred to us in the course of this work

H A, aged thirteen, had injured his left knee in a fall from a horse, two years previous to our examination He was in bed for six weeks and was told that he had injured his knee cartilage He was not given any type of physical therapy or special exercise in the convalescent period His knee continued to bother him "on and off whenever I do much" He was a sturdy young boy, weighing 120 pounds, who wanted to play football The examination of the knee was negative, and there was no evidence of quadriceps atrophy He was told, however, that his muscle strength (he could raise twenty-five pounds on the boot and extend forty-five pounds on the hip-knee extension exerciser) was not good enough for the stress which football could offer, six-man football (a less hazardous game [5]) and an exercise program were suggested After eight weeks of this exercise program he was raising sixty pounds and extending ninety pounds, during the next six months there were no symptoms referable to the knee, despite strenuous participation in athletics A check six months after he had discontinued therapeutic exercise, showed no loss in ability to extend these weights The details of his weekly prescriptions (Table II) illustrate the "progressive" principle of this technique Periodic increase in the maximum load is an essential part of this method

I C badly twisted his right knee while skiing on February 23, 1947 He was admitted to the hospital where, on February 24, he was found to have considerable fluid in the knee joint, pain with all motion of the joint, and exquisite tenderness over the medial condyle He had been treated with an ice pack initially, then with a tight compression bandage After a few days of bed rest, the fluid disappeared He was discharged from the hospital on March 3, without crutches, but with a supporting felt bandage A period of quadriceps-setting and straight-leg-raising exercises followed On April 5, 1947, a series of quadriceps measurements showed atrophy of the right quadriceps of from one-half to one inch at various points Against a heavy spring scale he could extend his right leg against forty pounds, his left leg against sixty-five In the hip-knee extension exerciser he extended twenty-five pounds with his right leg and thirty-five pounds with his left; he could raise only ten pounds on the boot with his right leg After seven weeks of exercise he was able to raise forty-five pounds on the boot and to extend eighty pounds Twelve months later he was still able to raise fifty pounds on the boot

J. I. was operated upon in June 1947, and a ruptured medial meniscus was removed. He was given no ostoperative exercise and was told "to be careful for a few months". He consulted us in October 1947. His nee seemed to be in fine condition and there was no atrophy of the thigh but he could raise no more than fteen pounds with his right leg (thirty-five with his left) and could extend only fifty pounds (eighty pounds ith his left). This finding of strength differences when the loads are large, in the presence of an otherwise egative clinical examination, seems to us to be important. The joint motions are satisfactory, there is no uid, the knee seems strong when the leg is raised against the examiner's hand, but there is relative weak- ess. After six weeks of treatment, J. I. was able to raise 75 pounds and to extend 100 pounds. Six months ater he reported that he had had no trouble with his knee in the interval; a test showed that he had lost ery little, if any, of his quadriceps power.

J. I. twisted his right knee while wrestling in June 1946; it did not seem to be a severe injury, and no eatment was given other than the application of an elastic bandage. In September 1946, the same knee went out" at soccer, and he refrained from athletics for two weeks. In December he twisted his knee and ll in the shower bath. During the following spring and summer the knee bothered him but he kept on ying various activities. In September 1947 his knee "went out" again at soccer and, completely discour- zed, he decided to give up athletics. When seen by one of us on September 26, 1947, the knee seemed nor- al, there was no evidence of instability, no fluid, no crepitus or pain with motion, no atrophy of the thigh nd apparently good strength. The right leg, however, was able to lift only thirty pounds, while the left used forty. After a seven-week program of progressive-resistance exercises, the right leg handled seventy ounds on the boot and increased its ability to extend from 55 to 105 pounds. During a test, five months ter, he was still able to handle these amounts and had had no symptoms despite an active athletic career uring the winter and spring of 1948.

A. G. first had trouble with his left knee in October 1946; at that time there was evidently a considerable fusion in the joint and he was told that he had a "loose cartilage". A plaster cast was applied for three eeks, then diathermy treatments were given twice a week for six weeks, together with some quadriceps- tting exercises. In December 1946 he played basketball and injured his knee again; some fluid developed, ut he tried skiing later that winter. He played baseball and tennis in the spring without difficulty. In Sep- mber 1947 he slipped on a boat deck and wrenched his knee; fluid developed. When first examined by us eptember 1947) there was a small amount of fluid in the left knee joint, but no tenderness to pressure or ain on motion; atrophy of the quadriceps was marked. The left leg could raise no more than five-eighths of pound on the boot, and that was accompanied by apprehension and difficulty. A week later, when his con- dence had been gained, he raised five pounds, which is undoubtedly a better measure of his initial strength. t the same time he lifted thirty pounds and extended sixty-five pounds without difficulty with his right g, whereas he could extend no more than thirty-five pounds with his left. After ten weeks of exercise, he ised seventy pounds on the boot and extended ninety pounds with his left leg. A test nine months later owed no loss of power, and he had had no symptoms during these months.

K. S. dislocated his right knee (patella) while diving on July 25, 1947; a plaster cast was used until ugust 15. Fluid was present when the cast was removed, and diathermy and a whirlpool bath three times week were ordered until September 12. When seen on September 15, he was still using crutches, and exion and extension at the knee were considerably limited. There was no evidence of fluid, but there was arked atrophy of the right thigh,—from one-half to one and one-half inches in serial measurements. His ght leg raised seventeen and one-half pounds on the boot, his left raised forty; the right extended thirty- ve pounds, the left sixty-five. After nine weeks of progressive-resistance exercises he raised 65 pounds and xtended 105 pounds with his right leg.

In these cases, not only has the atrophy or weakness of the thigh muscles been over- ome, but the individual's ability to overcome weight resistance has been greatly in- reased over what we can presume was his ability prior to injury. This was accomplished ith only a small expenditure of time; ten minutes a day is adequate. Patient coopera- ion is easy to obtain; these boys eagerly watched their charts and the gradual increase n power which they showed. The exercises, because they continually increase in diffi- ulty, are challenging. They do not seem to be the same day after day, because the amount of weight is increasing and the numerical values act as an incentive and furnish the physi- ian with an objective measure of progress.

The relatively rapid loss of cardiovascular-pulmonary endurance after cessation of a training program is well known[11]. The persistence of the weight-resisting ability is obviously much greater; there has been no significant loss in any of these cases. Exactly

what these exercises accomplish is not clear, the increase in weight which can be handled (in A. G. from five to seventy pounds and in J. F. from thirty to seventy pounds) cannot be thought of as representing a parallel increase in muscle mass or even in muscle strength. Learning factors at the cerebral level[10] undoubtedly play a part. Whatever the mechanism, atrophy has been overcome, and ability to raise or extend weight has been vastly increased. After the exercise program, each patient has felt much more confident of his knee's ability to withstand strain, and in none have any significant knee injuries developed subsequently. Obviously many more cases must be studied and a much longer period of observation must elapse before one can properly be optimistic. These preliminary observations, however, at least suggest the justification of further clinical tests of these methods.

LOW-BACK STRAINS

Symptoms of low-back strain are common in adolescence. During this period of rapid growth and strenuous, but poorly coordinated, exertion, there is frequently insufficient strength of the low-back muscles to prevent excessive strain being put on the lumbar and sacro-iliac ligaments. More uncommon disorders than postural or ligamentous strain, such as spondylolisthesis and epiphysitis, need to be kept in mind, and careful clinical and roentgenographic examinations of even the most transitory low-back symptoms are essential.

Experience to date indicates that progressive-resistance exercises in spondylolisthesis are tolerated well, often with relief of subjective symptoms. However, back symptoms may occasionally develop in patients with juvenile epiphysitis, probably due to excessive tension on the involved areas. Therefore, resistance exercises in these parts are advised with greater caution.

During the acute phase of low-back strain, bed rest, strapping, heat, and codeine and aspirin may be necessary. Later the patient should avoid lifting, a slumped position while sitting, and standing with the weight on one foot. Sleeping on a bed board, the daily performance of flexion and extension, and pelvis-tilting exercises are properly given. However, to prevent the recurrence of these symptoms, it would seem wise to attempt to increase the strength of the sacrospinalis[7]. This procedure may also be of value in the after-care of those who have previously had braces or casts applied. Data concerning nine

TABLE III

TRUNK-HYPEREXTENSION EXERCISE IN NINE BOYS

Patient	Age	Height (*Inches*)	Weight (*Pounds*)	Diagnosis	No. of Exercise Periods	Initial Maximum Power (*Pounds*)	Final Maximum Power (*Pounds*)	Maximum Power at Re-test (*Pounds*)
G. M.	17	74	181	Spondylolisthesis	10	10	25	
					20*	25*	70*	75 (6)**
J. B.	17	74	178	Low-back strain	18	45	65	75 (9)**
R. C.	16	70	150	Low-back strain	16	35	70	
N. K.	17	69	173	Low-back strain	24	20	80	
M. L.	16	69	138	Low-back strain	21	20	50	55 (12)**
R. S.	15	69	133	Low-back strain	36	20	65	75 (12)**
J. W.	18	69	155	Low-back strain	48	30	125	
H. M.	16	72	165	Epiphysitis, spine	24	20	50	
G. T.	18	69	128	Low-back strain	24	20	60	

* Second series, nine months later.

** Interval in months between exercise and re-test.

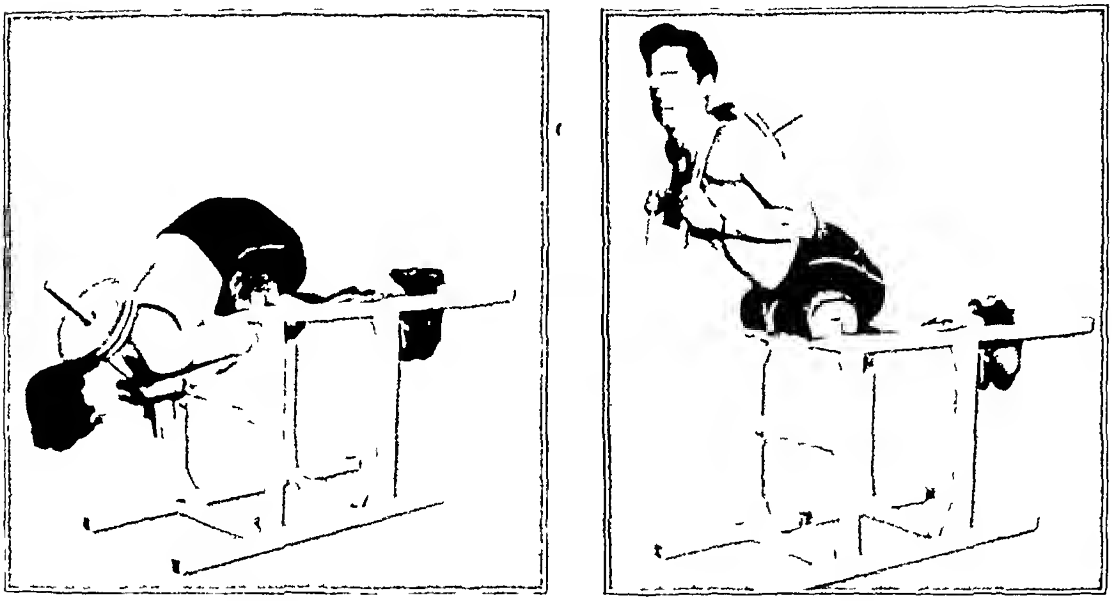

FIG 3-A FIG 3-B

Load-resisting exercise for hyperextension of trunk

of these cases are given in Table III The exercise method is illustrated in Figures 3-A and 3-B

R C first hurt his back while pole-vaulting, in April 1947 In the early fall of that year his back was bothersome, and he decided to stop playing football On October 9, 1947, roentgenograms were negative, there was slight limitation of forward bending, but no pain Since there were no acute symptoms, progressive-resistance exercises were begun The load-resisting trunk-hyperextension exercise (Figs 3-A and 3-B), with weight placed between the shoulders just below the neck and with knees supported and feet firmly held, was done thirty times a day During the first week twenty-five pounds was raised ten times, thirty pounds ten times, and thirty-five pounds ten times on each day During the fourth week seventy pounds could be raised No further symptoms developed, despite a resumption of pole-vaulting during the winter and spring Five months later sixty pounds was raised without difficulty

N K, a sturdy and very athletic lad, first injured his back at football (tackling) in 1943, he was taped and was allowed to continue playing In 1945 his back again bothered him In the spring of 1947 he injured it at pole-vaulting and had to give up that sport All through the football season of 1947 it bothered him, but he continued to play, it would feel tired and "sore" at night At the start of early-season basketball, his back hurt whenever he jumped At examination on November 13, 1947, when he finally reported his symptom to one of us (he had thought nothing could be done!), his roentgenograms were negative and so was his clinical examination, except for less flexibility in forward bending than one would expect in an athlete Despite his excellent development and athletic skill, he could raise no more than twenty pounds when doing the back-extension exercise During a three-month period of treatment (interrupted by the Christmas holidays) there were twenty-four exercise days, in this time he became able to raise eighty pounds After the first week in January he had no further symptoms of back strain, and played basketball vigorously and without any discomfort

R S first hurt his back in March 1947, while playing basketball out-of-doors, he was unable to sleep that night Roentgenograms were taken, aspirin was ordered, and he was told to "take it easy" He recovered gradually and had no further trouble until spring, when he started to play lacrosse, his back was taped and he was told to rest for one month At the end of May he played lacrosse again, but almost immediately his back started to hurt, so he stopped In August, while swimming, it bothered and an osteopath made his bones "click" In the fall he tried football, but stated that his back hurt every day Without much hope of obtaining relief, he consulted one of us on November 9, 1947 The roentgenograms were negative, and no abnormality was noted except discomfort during extreme forward bending Progressive-resistance exercises, beginning with twenty pounds, were continued for two months (interrupted by the Christmas holidays) After thirty-six exercise periods, he could raise sixty-five pounds At the end of four weeks (sixteen visits) he was able to hyperextend his trunk and fifty-five pounds, and later reported that during the Christmas holidays he shoveled heavy snow for three hours without discomfort He wrestled during the winter and

played lacrosse during the spring without discomfort. Twelve months later he reported that he had had no symptoms of back strain since stopping his therapeutic exercise, and he was able to raise seventy-five pounds.

G. T., a physician's son, wrenched his back when he tripped going upstairs on February 27, 1947; it was very painful for him to straighten up, to walk, or to turn in bed. He was seen the next day; only slight forward bending was possible, and the lumbar muscles were in spasm. He was put to bed and given medication and heat. He gradually improved, so that one week later he could walk with comfort. Roentgenograms were negative. Because of the severity of that acute attack (there had been two similar attacks previously), progressive-resistance exercises were not started until April 7. At that time he was able to raise twenty pounds; six weeks later he was raising sixty pounds. Eighteen months later he reported that he had no further back pain.

H. M. had low-back discomfort in August 1945, and roentgenograms showed definite epiphysitis of the spine. A brace was worn until March 1947. With the consent of his specialist, progressive-resistance exercises were begun in April 1947, the back-extension exercise started with twenty pounds and increased to fifty pounds in six weeks. The patient subsequently engaged in a strenuous athletic program without difficulty.

J. W. fractured his coccyx in 1943. In December 1947, he returned to his physician for an annual check-up. He was told that he probably would have trouble with his back at the age of forty, and was urged, as he had been during the previous four years, to continue to take it easy at athletics. After his return to school he came in requesting a bed board, because his back ached sometimes. Roentgenograms and clinical examination of his back were negative, his abdomen was prominent, and the muscles in general were rather flabby. Despite his lack of interest in exercise and athletics, he said he wanted to get rid of his prominent abdomen and wouldn't mind seeing if he could prevent his backache and avoid the trouble promised for the age of forty. With some skepticism and a little indifference, he began back-extension exercises on January 26 with twenty-two and one-half pounds, and continued until May 14, when he was able to raise 125 pounds. Concurrently he did "sit-ups", first against only his own weight, and finally doing thirty a day with twenty pounds held by his hands behind his neck. He had no symptoms of back strain after March 1 and slept without any discomfort. In May his muscles were firm, his attitude and spirits had improved, and his abdomen was no longer prominent.

There has been an opportunity to test four of the nine boys at intervals of from six to twelve months after the special exercise had been discontinued. In no case was there a loss in ability to raise the amount of weight which had been their previous maximum (Table III).

CHEST AND ARM DEVELOPMENT

Examinations of adolescents which seek ways to improve health and fitness, as well as to uncover abnormalities[4], will frequently reveal youths whose arms are extremely thin, whose chests are flat, and whose shoulder girdles are poorly developed. It would

TABLE IV

EXERCISES FOR THE DEVELOPMENT OF ARMS, CHEST, AND SHOULDER GIRDLE IN EIGHT BOYS

Patient	Age	Height (*Inches*)	Weight (*Pounds*)	No. of Exercise Periods	Curl *	Alternate Press *	Side Arm-Raising *	Side Arm Raising (Lying) *
I. C.	14	65	99	40	15–25	10–15	5–8¼	5–8[illegible]
C. C.	15	71	126	36	30–50	12½–20	5–11¼	7½–13¾
J. G.	14	64	110	60	20–32½	7½–11¼	2½–6¼	2½–8¾
L. K.	14	62	91	32	20–30	7½–15	2½–6¼	2½–7[illegible]
C. P.	17	69	132	46	35–60	12½–30	5–10	7½–17[illegible]
A. P.	15	71	172	24	20–50	10–25	2½–8¼	5–10
H. S.	16	68	127	36	25–45	10–20	6¼–10	7½–11¼
J. S.	15	69	133	36	30–45	10–20	5–8¼	5–12

* The first number represents the initial maximum power, the second number the final maximum powe[r]

seem reasonable to believe that improvement in these conditions would be beneficial. The youth who does not wish to be bigger and stronger is rare, and, if for no other reason than to satisfy these wishes, it is proper to try to help him. To take the position that brains are all-important and to deny the part that brawn plays in an adolescent's mental health and adjustment is unfortunate. These exercises may be considered more properly a part of a physical-education program than the concern of the physician, pediatrician, orthopaedic specialist, or physical therapist, but often they can be combined with exercises for the back, knees, or some other region which brings the patient in for treatment. Too few physical educators or athletic coaches spend much effort in the improvement of strength of the less able athletes; many of them are interested chiefly in the development of skill and in the psychological values of games. An indication of the sort of gains which can be made is given by the data in Table IV.

J. C. came in for quadriceps exercises but wished also to build up his chest, arms, and shoulders. Over a period of ten weeks he made considerable gains in ability to handle increasing amounts of weight in doing each of four exercises.

J. G. is of interest because his exercise period was interrupted and because he was again tested after a nine-month interval without similar exercise. In this nine-month interval he had taken part in a regular school program of soccer, basketball, and lacrosse, and yet, although there was no loss in ability to handle as much weight as he had done nine months previously, it was difficult for him to do so and there certainly had been no gains in strength. In sixty exercise periods (Table IV) his ability to handle weight increased from 50 to 250 per cent. for the various exercises.

CONCLUSIONS

On the basis of this preliminary experience with progressive-resistance exercises in these conditions of adolescence, it seems obvious that the method is a valuable adjunct to other physical-therapy procedures. The objective nature of the exercises, the fact that numerical values can be assigned and progress charts kept, and the fact that new and strange equipment is used all contribute to the patients' interest and cooperation. It would appear that the benefits of these procedures persist over a considerable length of time; further study of this point is obviously necessary. More investigation of the nature of the improvement in ability to handle weight is also needed. Other factors than muscle hypertrophy must exist to explain the changes noted. The concomitant improvement in the contralateral limb has not been discussed, but in each of these cases it has been noted, and it has been described by Hellebrandt, Parrish, and Houtz.

SUMMARY

1. This preliminary report suggests the effectiveness of the technique of progressive-resistance exercise in the after-care of knee injuries and low-back strains and in the development of the muscles of the upper trunk and arms of adolescents.

2. The desirability of utilizing a therapeutic-exercise method which will not only restore muscle power, but which will also produce a considerable increase over the strength existing prior to injury, is urged.

3. Further clinical trial of progressive-resistance exercise is suggested in conditions which require that muscle power be increased.

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AN UNUSUAL FORM OF de QUERVAIN'S SYNDROME

Report of Two Cases*

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In most cases of de Quervain's syndrome, the tendons of the abductor pollicis longus and the extensor pollicis brevis are involved, as they pass diagonally downward in a common compartment over the styloid process of the radius [2] Occasionally the tendons lie in separate compartments, and the pathological process may involve either or both [3] (Fig 1) In the cases reported here, the constriction was limited to the tendon and separate sheath of the extensor pollicis brevis

Case 1 A negro dishwasher, forty-seven years old, complained that pain in the left wrist had persisted for five weeks The pain was especially severe on adduction and passive ulnar deviation of the thumb Localized swelling, heat, and tenderness were present just above the radial styloid process

At operation, under the ischaemia produced by a pneumatic tourniquet, the superficial branches of the radial nerve were identified and retracted A transverse incision was used to avoid the ugly keloid frequently seen after longitudinal incisions The tendons of the abductor pollicis longus and extensor pollicis brevis lay

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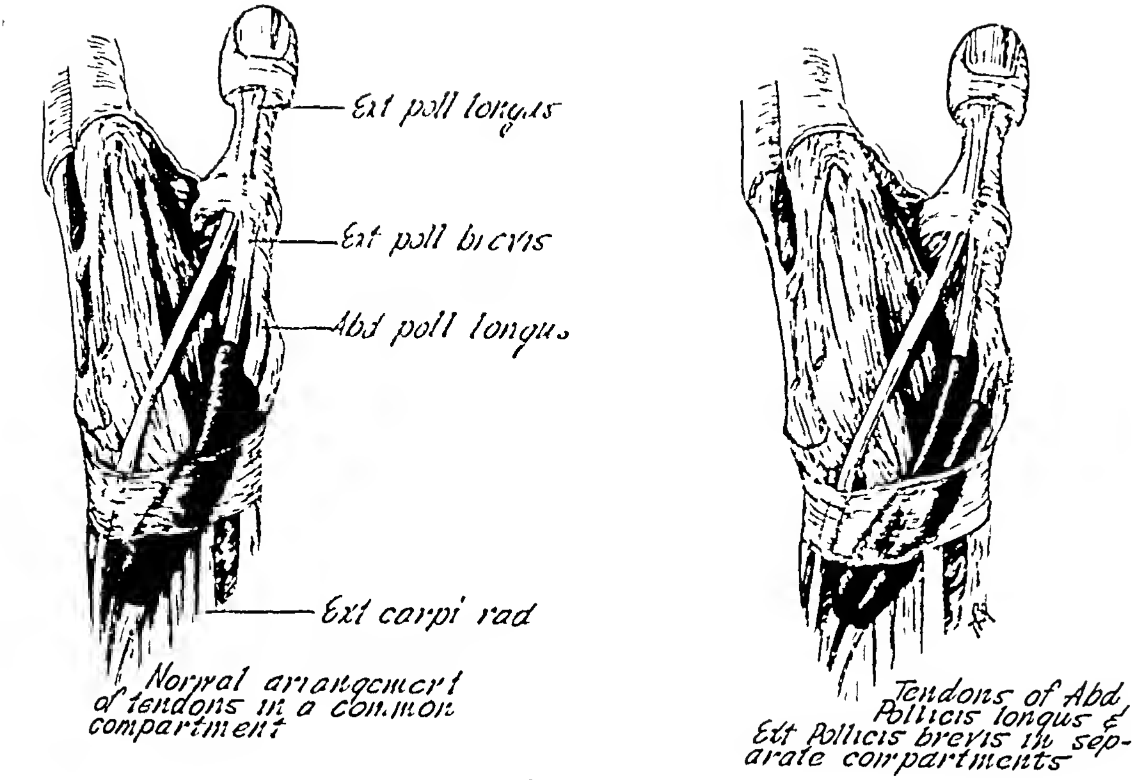

FIG. 1

in separate compartments (Fig. 1). The sheath over the abductor tendon was opened and was found to be of normal appearance. A probe was easily slipped up and down the sheath beneath the dorsal carpal ligament, and no aberrant tendon was encountered, as is frequently reported[1]. The sheath of the extensor pollicis brevis was next incised; it was thickened, discolored a reddish-brown, and contained yellowish fluid. Probing revealed the constriction to be one inch above the radial styloid process. A section of the dorsal carpal ligament and the sheath was excised longitudinally to a point well above the constriction, and the tendon then moved freely in its compartment with abduction of the thumb. Only the subcutaneous tissues and skin were closed.

Microscopic section revealed synovial tissue of tendon-sheath origin, lined by proliferated and hypertrophied mesothelial cells, the stroma of which presented moderate fibrosis. Recovery was uneventful; six weeks later the patient was working and had no symptoms.

CASE 2. Symptoms identical with those of Case 1 had been present for two months in a seventy-year-old white retired textile manufacturer, whose most strenuous activity for the past five years had been golf. The pathological findings were also the same, being confined to the tendon of the extensor pollicis brevis, which was in a separate compartment. As in the first case, the treatment consisted in removing a section of the dorsal carpal ligament and sheath at the point of constriction. Immediately afterward, the patient could fully abduct and extend the thumb.

In these two cases with symptoms of de Quervain's syndrome, the constriction involved only the extensor pollicis brevis, which was in a separate compartment. When this less usual arrangement of the tendons occurs, exploration of both compartments is advised.

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A METHOD OF PROCURING ILIAC BONE BY TREPHINE CURETTAGE

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An easy method of procuring cancellous bone from either the anterior or the posterio portion of the iliac wing is presented Essentially, it requires a one-inch incision, strippin of a small portion of the crest, and the excision of a piece of cortex sufficient to admit a medium-sized curette This is followed by complete curettement, bone being taken from a 45-degree arc in each direction (Fig 1) The use of a suction apparatus facilitates th procedure considerably Before closure of the incision, it is advisable to pack the cavit with a hemostatic substance, such as gelfoam, to prevent the formation of hematoma

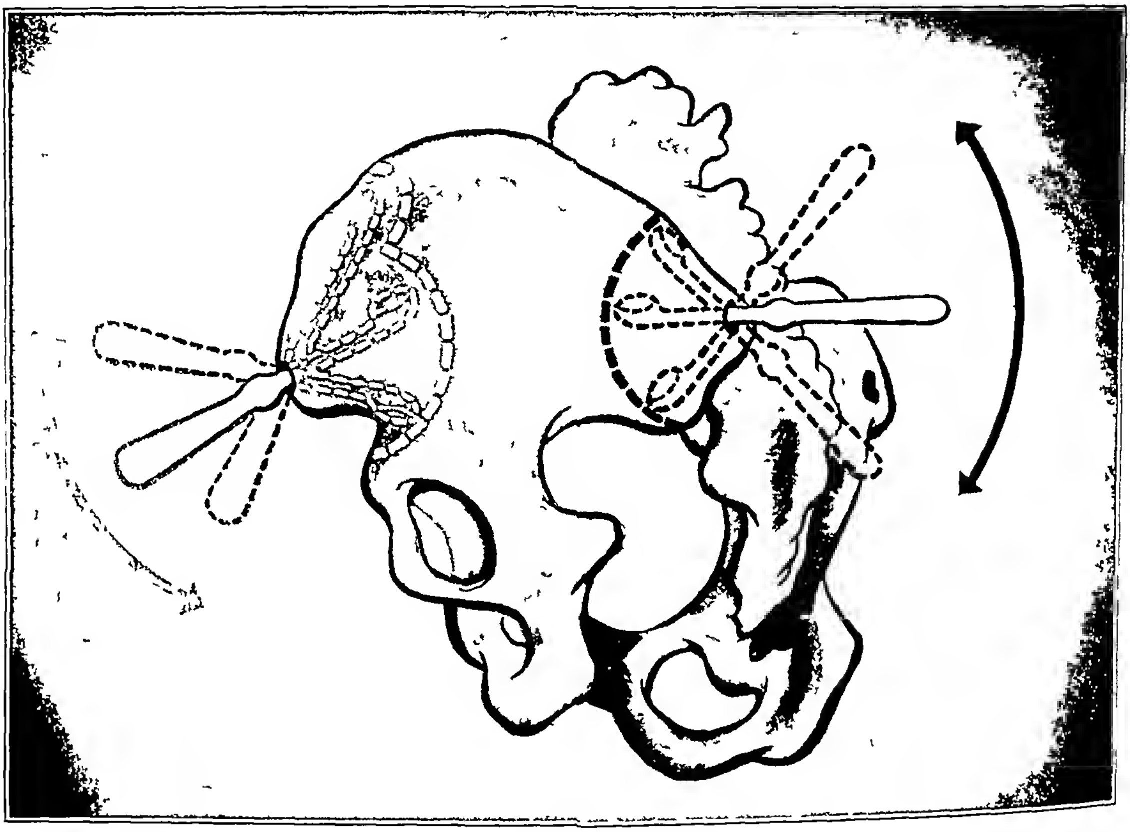

FIG 1

This procedure has been used by the authors in approximately 150 cases There have been no complications, and, as there is practically no shock, the method can be used in the aged patient or in the acutely injured, where the conventional and more extensive iliac operations are precluded

In our experience, curettings are superior to cancellous chips, cubes, or slivers, principally because the material can be better molded and packed into the bone cavities at the recipient site Muscle stripping is entirely eliminated, making early ambulation possible

VITALLIUM-CUP ARTHROPLASTY OF THE HIP JOINT

Review of Approximately One Hundred Cases *

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There are two qualities that every joint should possess,—stability and mobility. In the upper limb, mobility is the keynote; in the lower limb stability is more important. In the hip joint, stability is largely assured by the massive construction and comparative fixity of the pelvic girdle, while mobility is provided for by the presence of a ball-and-socket joint, permitting movement in all directions.

In order that this enarthrodial joint may function at its best, the position of the fulcrum must be at an exact distance from the line of the center of gravity. If fulcrum and line of gravity are approximated, stability may be increased, but there is a loss of mobility; if they are distracted beyond the normal, there is a loss of both stability and mobility. If the "machining" of the joint components be defective or the lubricating mechanism imperfect, there is a loss of efficiency; and if the muscle control is deficient, the same result accrues. Of all the factors necessary to the smooth working of a hip joint, probably failure of muscle control is the earliest to make itself manifest. The work of Inman has demonstrated beautifully the muscular mechanics of the hip joint in regard to the movement of abduction. The factor of distraction of the head of the femur was dealt with by Gilmour under the caption "Increased Acetabular Depth". Wiberg has emphasized this and has suggested a method of measurement.

It seems a natural inference that this outward passage of the head is due to inadequacy of the muscles which serve to hold it in the acetabulum. These are muscles of which we hear comparatively little; they are of considerable mass and they run for the most part

TABLE I

Measures for the Relief of Pain

Manipulation	Drilling of the head of the femur
Osteotomy	Division of the obturator nerve
Cheilotomy	Division of the fourth lumbar root
Joint debridement	Acetabuloplasty
Reconstruction (Whitman or Colonna)	Capsulectomy
Bone block	Chordotomy
Muscle-flap transplant	Arthroplasty (either without any barrier, with fascia, or with some form of mold)

transversely from the pelvis to the upper end of the shaft of the femur. These muscles are the pectineus, quadratus femoris, adductor magnus (uppermost portion known as adductor minimus), piriformis, obturator externus, and obturator internus with the two gemelli. This reasoning suggests that muscular insufficiency is an important factor in the development of osteo-arthritis of the hip joint, and that the deformities of the head of the femur and of the acetabulum are not merely phenomena of degeneration, but are partly physiological bone reactions to misdirected physical strains. This would align the condition with what is seen so frequently in the lumbar spine, and would suggest the value of muscular exercise, preferably without weight-bearing, as a prophylactic measure.

The osteo-arthritic hip has one outstanding symptom, pain, and one outstanding sign, limitation of movement. Of the two, pain is the more insistent problem. For its alleviation, many measures have been adopted (Table I).

* Read at the Joint Meeting of The American Orthopaedic Association, The British Orthopaedic Association, and The Canadian Orthopaedic Association, Quebec, Canada, June 4, 1948.

TABLE II

Disability	Number of Cases
Osteo-arthritis	89
Atrophic arthritis	9
Marie-Strumpell disease	3
Ununited fracture	3
Tuberculosis	2
Slipped epiphysis (old)	2
Septic arthritis	2
Fracture-dislocation	1
Total	111

The present paper deals with about one hundred cases in which a Vitallium cup was employed, following the method of Smith-Petersen It is in no sense a scientific memorandum The patients came mainly from long distances, their stay in the hospital was for the most part limited by financial and other considerations In the majority of cases there was only perfunctory after-care, and many of the patients have not been heard from directly since they left the hospital Indirect reports have been numerous, but in most instances it has not been possible to check progress Thus it is a series of impressions rather than a statistical survey that is presented

Age of the Patient

The average age was 52 6 years, the oldest patient was seventy-six, the youngest sixteen While there has been some improvement in the older patients, notably in regard to pain, the results have been rather disappointing In older people there is not the capacity for exercise and the will to improve that are seen in younger individuals We have tended to set the age of sixty-five as an arbitrary upper limit for this procedure On the other hand, the two youngest patients, aged twenty-three and sixteen, gave poor results The most encouraging progress was made by patients in the fifth decade

Stage of the Disability

Most of the patients treated surgically were in a fairly advanced condition with much osteophytic outgrowth, loss of articular cartilage, and limitation of movement The author has moved toward the position that an earlier attack on the problem, before these changes had become so marked, would have given better results In a community where most of the population live by physical labor on the farm or on the railroad medical aid is not sought until the malady has become disabling or the pain intolerable

Cause of the Disability

The causes of disability are indicated in Table II The cases of osteo-arthritis were, on the whole, suitable for this form of treatment Atrophic arthritis proved less satisfactory, and the cases of Marie-Strumpell disease were wholly disappointing Of the two cases of tuberculosis, in one the procedure was undertaken deliberately and in the other the infection was a belated discovery In both the treatment failed, both patients had arthrodesis later with satisfactory outcome Of the three cases of ununited fracture of the neck of the femur, one had a satisfactory result and the other two did not Of the two cases of slipped epiphysis, one patient, aged thirty-three, is at latest report free from pain, but is still using a crutch The other, aged sixty-one, suffered dislocation of the cup from the acetabulum, the roof being very sloping Fusion of the joint was performed later Of the two cases of septic arthritis, gradual stiffening occurred in one, at a later date

TABLE III

Result	Number of Cases
Good	65
Satisfactory	16
Bad	19
Unclassified	11
Total	111

the head of the femur was excised The other was the result of a severe war injury The result while not spectacular, is regarded as a success, inasmuch as the patient is now able to drive a car and manages a small business of his own A good result was obtained in the case of fracture-dislocation

THE SURGICAL APPROACH

In every case, the hip joint was exposed by the "posterior" approach based upon that described by Kocher It has proved to be very simple thorough, extensible to any degree, and almost bloodless, it is unaccompanied by shock It is rarely necessary to tie a blood vessel, no patient has ever required or had a blood transfusion, and there has never been a hematoma in the wound There is no extensive detachment of muscle fibers from bone, the glutaeus medius and glutaeus minimus run no risk of shortening Replacement after reflection is easy and accurate There is no interference with the function of the iliotibial tract After recovery, the Trendelenburg sign is usually negative The description of this approach sounds complicated, in practice it is exceedingly simple As many surgeons seem to be unfamiliar with the method, a brief description is given herewith

The So-Called "Posterior" Approach *

1 The skin incision is made from a point about two inches (five centimeters) in front of the posterior superior spine of the ilium in a straight line or a slightly forward curve, downward to the upper anterior angle of the greater trochanter, from this point it passes vertically downward along the lateral aspect of the thigh for six or seven inches When the skin and fat have been reflected, the anterior border of the glutaeus maximus will be revealed

2 The fascia lata should be incised in the line of the femur This incision is followed upward along the anterior border of the glutaeus maximus, and the muscle is reflected backward This avoids bleeding from the muscle

3 The posterior border of the glutaeus medius is then evident, and is separated from the adjacent piriformis tendon The border is followed down to the insertion on the lateral aspect of the greater trochanter, and this insertion is detached with a flake of bone if necessary The operator should then proceed around to the anterior surface of the greater trochanter, and detach similarly the glutaeus minimus at its insertion Both of these muscles are reflected forward

4 The insertion of the piriformis is detached from the highest point on the greater trochanter, and the muscle is reflected backward The upper aspect of the capsule is then laid bare

5 The joint capsule is incised from the rim of the acetabulum to the upper aspect of the neck of the femur, thus opening the joint cavity

6 The femoral attachment of the capsule is detached from the anterior intertro-

* A more detailed description of this procedure will be included in an early issue of the British Volume of The Journal

chanteric line, as far as is necessary to provide easy egress for the head of the femur It is never necessary to touch the iliopsoas

7 The head of the femur is then dislocated through the opening in the upper anterior portion of the capsule The knee is flexed, the thigh is rotated strongly outward and is adducted When this has been done, the field of operation is completely in view

8 The periphery of the acetabulum is freed from excessive bone growth The floor of the acetabulum is inspected, and any loose pieces of bone or redundant synovial membrane are removed The bony floor is usually smooth and is not weakened by burring out compact bone

9 The head is remodeled roughly with an osteotome, then with a short wood rasp which is controlled with the finger tip, and finally with a reamer

10 The cup is fitted so that it moves easily and smoothly, but does not "rattle" The neck is freed from projecting spurs of bone

11 The cupped head is reinserted into the acetabulum by reversing the extrusion manoeuvre The flap of capsule is stitched back into position

12 The glutaeus medius and glutaeus minimus fold back into position and are stitched with catgut, the glutaeus maximus and fascia lata are similarly disposed of, the skin is closed with a continuous suture Although the wound is fourteen or fifteen inches long, it heals readily

Postoperative Treatment

The period spent in bed is usually four weeks, during which exercises are carried out Three principles are observed in regard to exercises

First, they are graded, as follows

1 Assisted The strain is eased by the use of pulleys and counter suspension

2 "Scratch" The limb is actively moved without assistance

3 Handicapped Resistance is added in the form of a weight which is systematically increased If weight is added too rapidly, progress is retarded

Second, the exercises are carried out in all directions In the case of a disabled knee joint, we are constantly adjured to institute "quadriceps" exercises Experience has shown that "hamstring" exercises are at least as important, and so, in the case of the hip joint, exercises must include flexion, extension, abduction, adduction, external rotation, and internal rotation Special attention is paid to abduction

Third, it is recognized that the movements of the hip joint and those of the lumbar spine are complementary, hence exercises for the back are carried out as faithfully as those for the hip itself

COMPLICATIONS

Breaking of the Cup In no case has this occurred

Infection In one case infection flared up suddenly during the third postoperative week As it did not respond to conservative measures, the cup was removed

Dislocation Dislocation occurred in three cases One of these was an ununited fracture of the neck of the femur in a woman weighing about 250 pounds The stump of the neck was too short A second occurred in a patient who had an attack of pneumonia shortly after returning home He lay constantly on the sound side, and the upper end of the femur was displaced from the cup It was replaced by manipulation nearly three years ago, and there has been no trouble since In the third case, the cup was displaced from the acetabulum It was an error of judgment to have placed a cup in a socket with an inadequate roof The error was corrected by subsequent arthrodesis

Bone Absorption A fairly constant finding was that the cup sinks into the depth of the acetabulum, and that the stump of the neck seems to shorten as if it also underwent absorption In some instances a layer of sclerosed bone seems to be laid down to oppose

Fig 1-B

Fig 1-A

Fig 1-A Case 1 September 8, 1949, ten years after operation Shows absorption of the neck and sinking of the cup into the acetabulum

Fig 1-B September 8, 1949 Lateral view of hip

FIG 2-A
Case 74 May 17, 1939, before operation

FIG 2-B
June 11, 1949, eight and one-half years after operation

this migration No pain accompanies this gradual displacement, although movement becomes less free The picture suggests that, at least in old cases, the main part of the movement in the reconstituted joint takes place between the upper end of the femur and the cup rather than between the cup and the acetabulum A corollary to this observation would seem to be that it is inadvisable to burr out the cavity of the acetabulum, as this procedure must expose softer bone to the pressure of the metal

Transient Drop-Foot This was noted in one case, and was attributed to stretching of the sciatic nerve in the process of extrusion of the head from the acetabulum In the customary exposure, the sciatic nerve is never seen

Spur Formation In one case, complaint of pain led to re-exposure of the hip A ridge of bone was present on the under side of the neck Removal of this spur (in 1941) gave complete and permanent relief

Suture Material In a few cases, stout silk was used to ensure firm closure of the capsule In two instances, these silk sutures worked out at a later date Apart from a chronic discharge, there was no inconvenience

BILATERAL CASES

There were five bilateral cases, with one death, this occurred six months after the second operation, as a result of arteriosclerosis with gangrene of the foot The results in the other four cases were satisfactory One patient has been operating a taxi since 1942, another, aged seventy-six, is still able to get about with canes, another is working on his farm A fifth patient, whose result had first been classified as "bad", came back to have the other hip made equally free from pain

MORBIDITY

There were no operative deaths Five patients have died since the operation, one referred to in the preceding paragraph, at the age of sixty-eight Another, aged seventy-six, died a month after operation from cerebral arteriosclerosis A third died from the same cause at the age of seventy-six, a fourth died five years after operation at the age of sixty

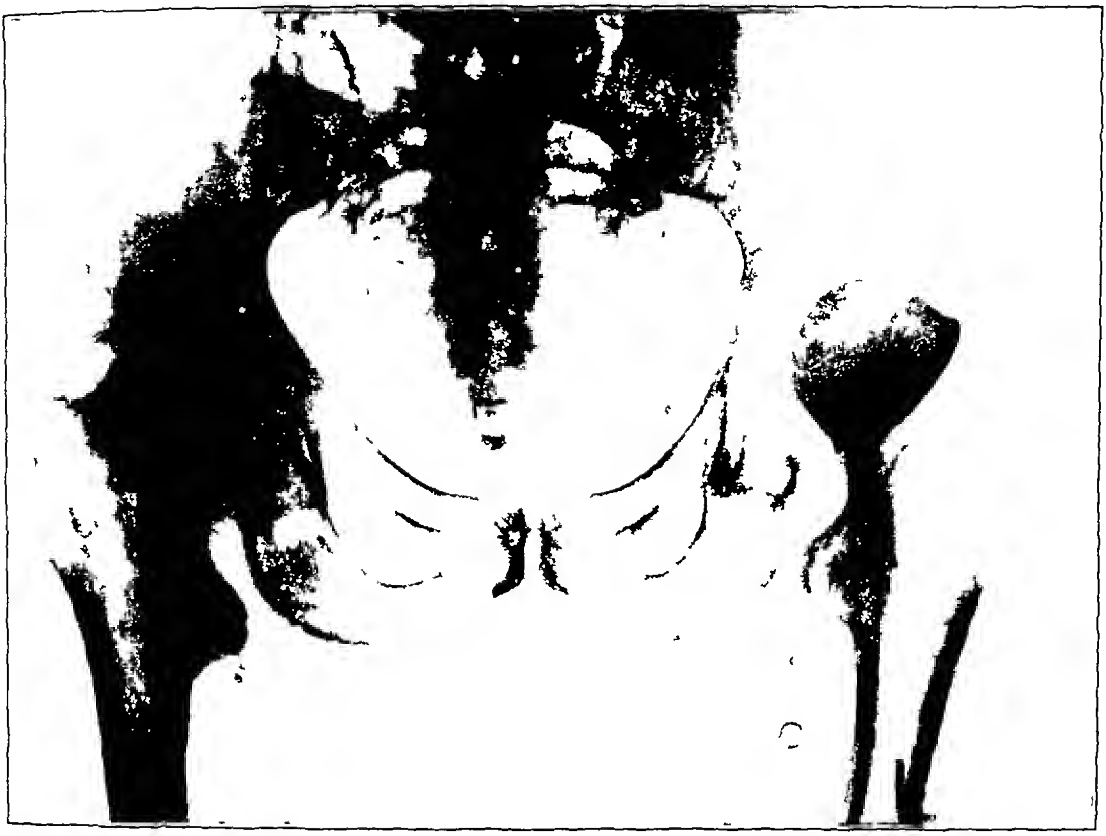

Fig 3

Case 43 Appearance of hips on May 14, 1946, sixteen months after second operation

nine, likewise from arteriosclerosis The fifth patient died one year after operation from secondary carcinomatous growths in the pleura and spine As far as is known, there have been no deaths among patients operated upon since 1942

RESULTS

It is impossible to present an accurate picture All cases should theoretically be considered under three categories,—anatomical, functional, and economic In considering movement alone, a three-dimensional joint demands three-dimensional coordinates which have to be correlated This would entail the use of an index of mobility, active and passive, checked at intervals,—a measure adopted in only a few cases of the present series The sole criterion used has been functional efficiency When the outstanding indication for operation is the relief of pain, it should be obvious that the patient must have a voice in estimating the result The result is considered "good" when the patient can earn his own living and indulge in a moderate amount of physical recreation, such as curling or golf He should also be able to put on his own socks and shoes, and should be able to stand firmly on the foot of the affected side Many have attained such results (Table III) A "satisfactory" result is one in which the patient is completely relieved of pain during his ordinary activities This has been attained in the great majority of cases A "bad" result is one in which the surgeon or patient, or both, are disappointed Of these, there are nineteen in this series They include the cases of tuberculosis, of Marie-Strumpell disease, and others which better selective judgment or better operative technique would have excluded

ARTHROPLASTY OR ARTHRODESIS?

Inevitably one ponders the question of arthroplasty or arthrodesis In some cases, such as tuberculosis, there is no choice, arthrodesis is imperative In other cases, where,

for example, there is bilateral ankylosis, an attempt to secure movement on at least one side is equally imperative. Both measures, if successful, give promise of relief from pain. If a reasonable degree of stability can be secured with, at the same time, a reasonable degree of mobility, then arthroplasty is the first choice. If only in a hip joint, a certain measure of freedom is surely worth the sacrifice of a modicum of security.

ILLUSTRATIVE CASE HISTORIES

CASE 1. A. le M., aged fifty-eight, a market-gardener, was completely disabled on account of osteo-arthritis of the hip. The operation was performed on July 3, 1939. He left the hospital in two weeks, had no postoperative treatment, and has been free from pain since. He regained good movement of the joint, was able to cross one leg over the other, and to sit in comfort through an entertainment. The patient was last seen on September 8, 1949 (Figs. 1-A and 1-B). There is still practically no pain, but the movement is less. He works from dawn to sunset, drives a car, and is satisfied. Functionally and economically, the result is good.

CASE 74. B. H., a stenographer, was operated upon at the age of thirty-eight. She had suffered from atrophic arthritis since the age of nineteen. Her left hip joint had been affected since 1938. The right knee was stiff (fibrous ankylosis) (Fig. 2-A). The operation was performed on January 5, 1941. The patient was in the hospital for four and one-half weeks, and did not use crutches after that time. She returned to work in from seven to eight weeks. This woman has had no pain since her operation, and has lost no time from work. Roentgenograms show considerable sinking of the cup into the acetabulum, and absorption of the neck of the femur. The patient was last seen on June 12, 1949 (Fig. 2-B).

CASE 43. J. P. had been a groom and a coachman; when seen, he was on old-age pension. He had marked osteo-arthritis of both hips with disabling pain. He was seventy-one at the time of his first operation, on June 16, 1943. He obtained relief from pain, and asked for an operation on the second hip. This was done on January 5, 1945 (Fig. 3). When last seen, on June 15, 1949, the patient walked with two canes, but stated that he was relatively free from pain unless he did too much. This case is classed as satisfactory, although the patient himself thinks the result is good.

CONCLUSIONS

1. Vitallium-cup arthroplasty offers good prospects of relief from pain and increased movement in cases of osteo-arthritis of the hip joint.
2. The "posterior" approach affords excellent exposure with little trauma.
3. Graded exercises in all directions are valuable for rehabilitation.
4. The procedure has not been found suitable in cases of tuberculosis, Marie-Strümpell disease, or sloping of the acetabular roof.

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DISCUSSION

DR. M. N. SMITH-PETERSEN, BOSTON, MASSACHUSETTS: I think Dr. Gibson has proved that, if we can do a thing well in our own way, we may occasionally succeed. He has demonstrated a different method of arthroplasty than the one we advocate. There are several points upon which we disagree.

I have always felt that, if we are to create a joint, we must create a joint that will be mechanically

(Continued on page 872)

POSTERIOR DISLOCATION OF THE HIP WITH FRACTURE OF THE HEAD OF THE FEMUR

BY EVERETT J. GORDON, M.D., AND JOSEPH A. FREIBERG, M.D., CINCINNATI, OHIO

From the Department of Orthopaedic Surgery, College of Medicine, University of Cincinnati

Traumatic dislocation of the hip comprises from 2 to 5 per cent of all traumatic dislocations. As the precipitating injury is always one of great violence, a complicating fracture is not uncommon; this usually involves the posterior rim of the acetabulum. A fracture of the head of the femur accompanying posterior dislocation of the hip is rare; it has been reported infrequently in the literature. Such a case is described here.

It is generally agreed that the cause of fracture of the head of the femur, in conjunction with posterior dislocation of the hip, is either direct trauma to the greater trochanter, or, more frequently, a powerful upward force exerted against the anterior aspect of a knee held in 90 degrees of flexion.

The fracture of the head of the femur appears to occur in its inferior or antero-inferior third; the fragment may be attached to the ligamentum teres and may or may not remain within the acetabulum, thus affecting the choice of procedure for reduction.

CASE REPORT

J. C. (Hospital No. 213614), a white male, thirty-two years old, was admitted to Cincinnati General Hospital on May 7, 1946, after the automobile which he had been driving had crashed into a tree. On initial

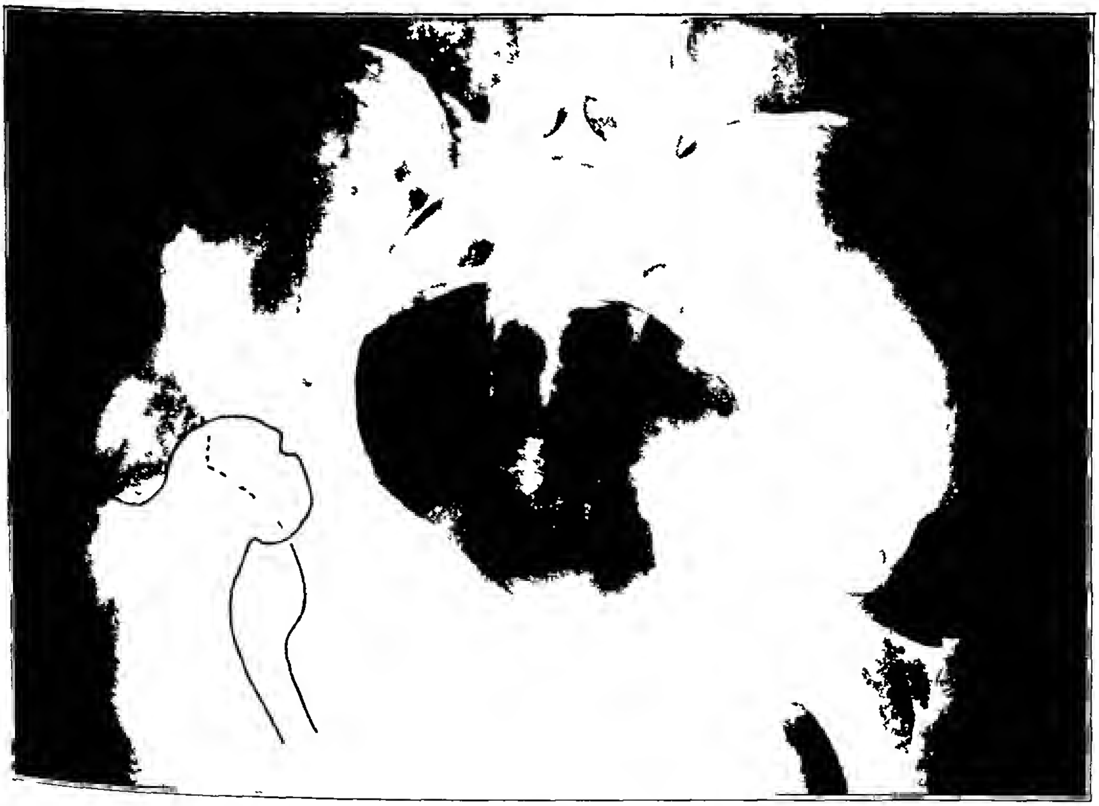

FIG. 1

Complete posterior luxation of femoral head. (Detached fragment from head is not demonstrable in this film.)

FIG 2

Femoral head has been completely reduced into the acetabulum

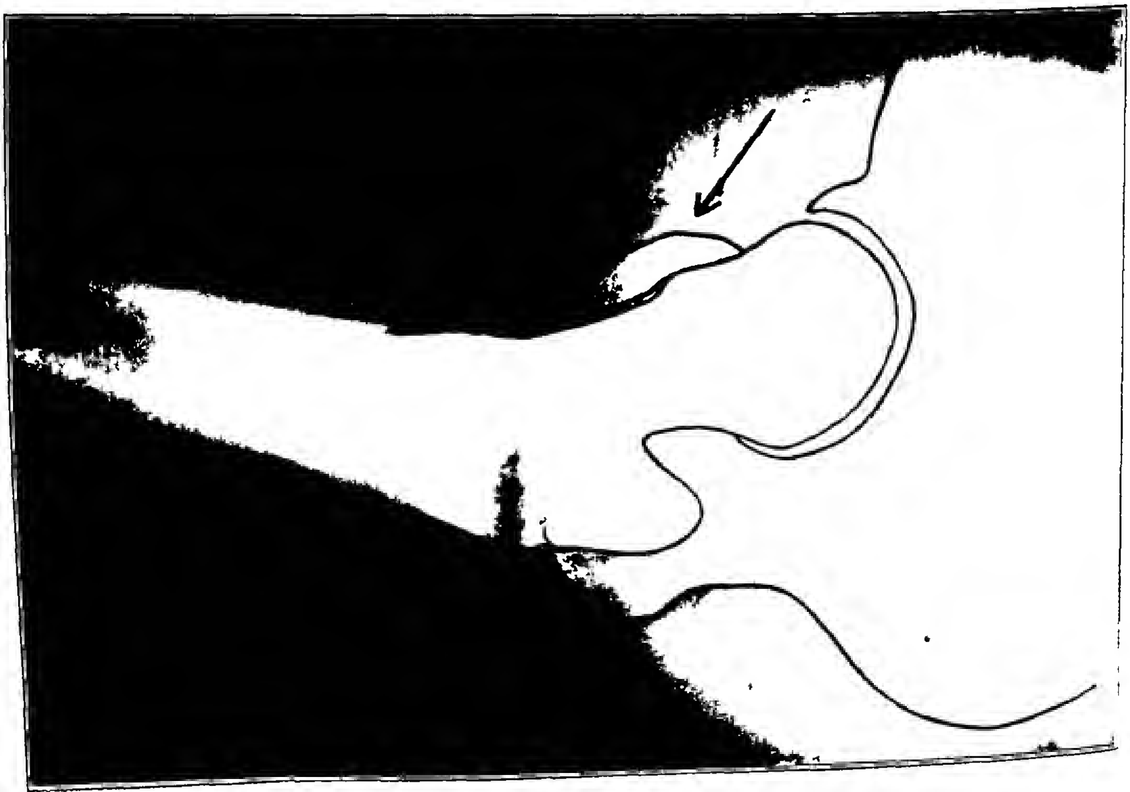

FIG 3

Intracapsular, detached osseous fragment is seen antero-infero-medially, no acetabular defect can be visualized

examination a severe scalp laceration was found, together with signs of cerebral concussion The right lower extremity was held in 20 degrees of abduction and 90 degrees of flexion at the hip joint The greater trochanter could be felt, high on the posterior crest of the ilium, and all movements of the right hip were painful There was a severely lacerated, compound fracture of the right patella with wide separation of the fragments

A diagnosis of posterior dislocation of the right hip was confirmed by roentgenogram (Fig 1), which, however, was insufficiently good to show the bony detail of the femoral head Reduction was difficult, but was finally accomplished, with the patient under intravenous pentothal anaesthesia, by direct, forceful traction with the hip flexed to 90 degrees Because of the cerebral injury and shock, for which two units each of plasma and blood were given, the patella and scalp injuries were repaired under local infiltration anaesthesia A wire suture approximated the patellar fragments, and the knee was immobilized with a massive Schanz dressing The hip was partially immobilized by binding the lower extremities together Convalescence was uneventful, the wounds healed *per primam*

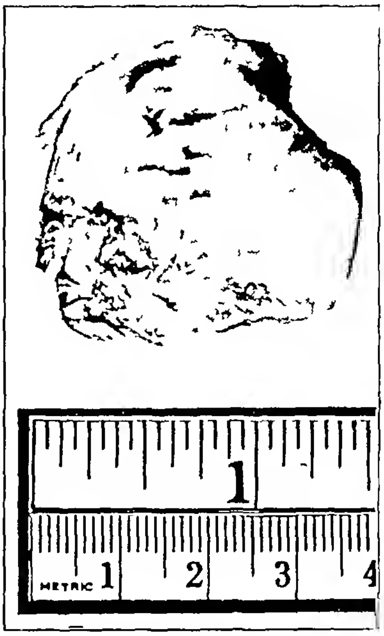

FIG 4

Roentgenograms, taken one week after admission (Fig 2) confirmed the reduction of the femoral head, but also showed a free fragment of bone within the joint capsule At first this was interpreted as a fracture of the posterior lip of the acetabulum, but when further studies, including stereoscopic views, showed the fragment to be lying anterior and infero-medial to the head and neck of the femur, it was decided that the loose fragment had been detached from the head of the femur and not from the acetabulum

Although there was a good range of painless motion in the hip, the hip was explored, three weeks after injury, through an anterior approach A large fragment of the femoral head from the articular surface of the antero-inferior portion, with a small ridge of adjacent

FIG 5

Fig 4 Specimen of detached fragment from antero-inferior surface of head of femur, with small portion of adjoining neck (Artifacts of articular surface from instrument handling)

Fig 5 Two years after injury, no avascular necrosis of head of femur is visible Sclerosis of inferior rim of acetabulum may be seen

cervical bone attached, was found tightly wedged beneath the joint capsule on the anterior aspect of the neck, joined to the neck by a synovial reflection This was removed, with another smaller fragment of loose articular cartilage (Fig 4) The defect in the antero-inferior portion of the head was visualized, but was not disturbed No fracture of the acetabular rim could be noted

Traction of fourteen pounds was applied through a Steinmann pin, placed in the supracondylar region of the femur, and was continued for six weeks This allowed early motion in the *injured* knee, which the patient soon was able to flex to 150 degrees Active physical therapy, including heat, massage, and active and passive exercises to both the knee and hip, resulted in continued improvement The patient was allowed up on crutches eleven weeks after injury, with an elevated shoe on the uninjured side to prevent weight bearing At that time hip motion consisted of flexion to 95 degrees, extension to 185 degrees, abduction to 25 degrees, adduction to 40 degrees, internal rotation to 20 degrees, and external rotation to 35 degrees Roentgenograms of the hip showed a normal outline of the femoral head, except for slight fuzziness of the antero-inferior portion

One month later, there was a complete range of painless motion in the hip The patient was very cooperative in the use of his crutches, apparently there was no weight-bearing on the affected side Weight-bearing was avoided for six months following injury, in the hope that adequate fibrocartilage might form over the denuded portion and that deformity of the femoral head from possible aseptic necrosis might be prevented Partial weight-bearing was then instituted, and the crutches were discarded two weeks later At that time the patient had no difficulty in using the right hip, and was able to return to his work at dry cleaning Three months later, he had a full range of painless motion in the hip, he walked without a limp, and was able to do a full day's work without fatigue Roentgenograms revealed the defect in the femoral head, but otherwise an essentially normal hip joint

The patient returned to the clinic on May 25, 1948, two years after injury, walking with a normal gait and with no complaints Examination showed no shortening of the right lower extremity and a normal range of motion in the hip, without pain Motion in the right knee had improved almost to normal Roentgenograms of the right hip suggested the possibility of a slightly superior position of the acetabulum (Fig 5), but otherwise essentially no change from the previous examination of February 11, 1947

By questionnaire in March 1949, the patient reported that he had a complete range of motion in the right hip as compared to the left, no limp, almost complete motion in the right knee, and no pain with weight bearing or walking He was able to do a full day's work without difficulty, and expressed the opinion that the hip was as good as it had been before the accident

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DISCUSSION

Vitallium-Cup Arthroplasty of the Hip Joint

(Continued from page 868)

efficient In order to bring this about, we must reconstruct both sides of the joint For this reason, the anterior approach, which gives access to the acetabulum, was developed Dr Gibson does not believe in this and has shown illustrations to demonstrate his point In conditions, such as malum coxae senilis, with overgrowth of bone on the acetabular side as well as a large femoral head, the posterior approach would be very disappointing and certainly not so easy as it appears to be in the film demonstrating the operation Reconstruction of the acetabulum must be done if we aim to lay the foundation for a joint that will function well permanently

Dr Gibson made a statement that the cup should not rock on the head The cup should rock on *the head*, it is not physiological for the head of the femur to be encased snugly in the mold There must be motion between the acetabulum and the mold, and between the femoral head and the mold If the cup fits snugly and does not rock, we will have motion between the mold and the acetabulum only A tightly fitting mold interferes with the circulation to the head and neck and, in the course of time, degenerative changes take place inside the mold, resulting in a distorted relationship between the mold and the adjacent structures

I am glad that Dr Gibson emphasized the need of careful postoperative treatment This is most important if the best possible results are to be obtained

Dr Alexander Gibson (closing) The cases in this series were essentially cases of osteo arthritis of the hip We had one or two other conditions, such as a shallow acetabulum, which in my experience has not been treated successfully It would demand a degree of excavation of the acetabulum that we have not done

In regard to the point brought up by Dr Smith-Petersen, when I said "rocking" I meant no movement from side to side The joint must never be stiff It has been our experience that the cup itself sinks into the bone and that the bulk of the movement is between the stump of the neck and the cup

SURGICAL APPROACH TO THE VERTEBRAL BODY

BY ARTHUR A. MICHELE, M.D., AND FREDERICK J. KRUEGER, M.D.,
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From the Department of Orthopaedic Surgery of the United States Marine Hospital, Staten Island, New York

Early vertebral lesions in which the pathological changes are confined to the vertebral body present a problem in their diagnosis. The present-day method of basing the diagnosis solely upon the findings of the roentgenologist and the clinical pathologist is not accurate in all instances. Only upon obtaining definite biopsy evidence can a sound diagnosis be made and the appropriate therapy instituted.[2] Needle biopsy of the thoracolumbar vertebrae is not only a blind and dangerous procedure, but frequently yields unreliable and inadequate material for diagnosis. The anterior or abdominal approach to the vertebrae is difficult and hazardous.

Since a safe method for obtaining adequate biopsy material has not been available, vertebral-body lesions have frequently been treated on an empirical basis with antibiotics, roentgen-ray therapy, or spine fusion. Consequently, several methods for penetration of the vertebral body through a posterior spinal approach, for the purpose of obtaining adequate biopsy and culture material, have been devised. By a direct approach to the vertebral body through definite bone channels which can be exposed readily, the selected portions of the body contents are made available for diagnosis and subsequent therapy. The method of choice for penetration of the thoracolumbar vertebral bodies will depend entirely upon the surgeon's dexterity and his familiarity with the anatomy of the structures involved.

FIG. 1

Transverse sections through the thoracic and lumbar vertebrae show the relative diameter of the pedicle as compared with that of the body.

The transverse diameter of the pedicles in relationship to the bodies of the thoracolumbar vertebrae is of greater proportion than that noted on examination of the mounted skeleton (Fig. 1). A trephine with bores of three-sixteenths of an inch, seven thirty-seconds of an inch, and five-sixteenths of an inch is used for penetration into the body. The gauge used is dependent upon the vertebral body under investigation. The marker is used for locating the centrum of the articular facets, over which the trephine is inserted (Fig. 2).

THORACIC VERTEBRAE

The bodies of the thoracic vertebrae may be approached by either of the two following methods.

Method I

The patient is placed in the prone position. A paravertebral incision is made over the side of the spinous process and over the laminal plate of the affected vertebra. The muscles are retracted and the transverse process is bared. A transverse osteotomy is performed at the base of the transverse process, at its juncture with the laminal plate (Fig. 3,*A*). By depressing or retracting the transverse process from the wound, the isthmus of the vertebra

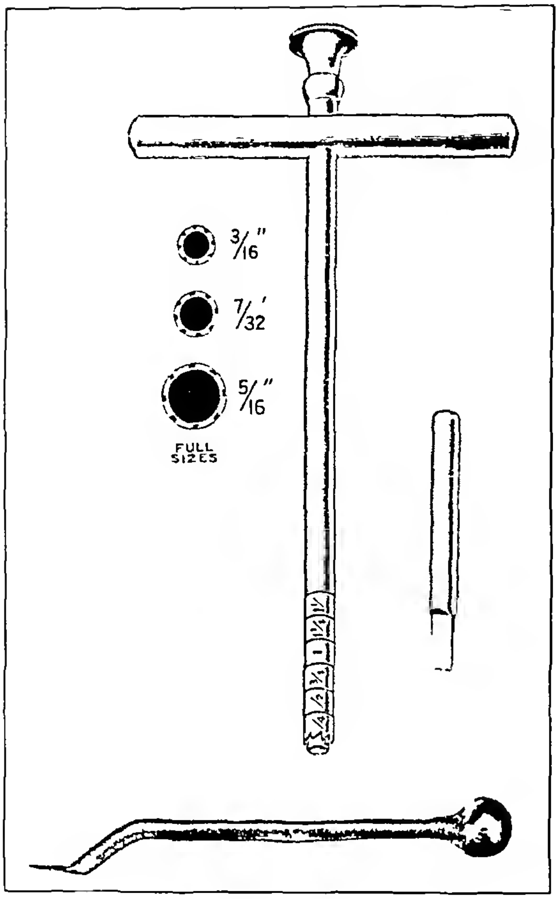

FIG 2

The trephine with stylet inserted, showing the three diameters The marker is used for a control in trephining the articular facet

is exposed and the cancellous nature of its bone structure may be seen A three-sixteenths-inch trephine with quarter-inch markings is inserted through the fenestra and guided downward with slight pressure, so that a mere twisting action leads the trephine into the pedicle and finally into the body (Fig 3,*B*) The trephine is removed repeatedly, after minute progressions within the channels have been made In each instance, the contents should consist of cancellous bone, which indicates the presence of the trephine within the medullary substance of the pedicle As a result of penetration by the trephine, a channel from the posterior elements directly into the vertebral body is formed, and spongy bone or pathological tissue can be removed readily with a small blunt curette If he so desires, the operator may use the trephine stylet instead of the trephine, inserting it through the cancellous isthmus into the canal of the pedicle and finally into the vertebral body Only gentle pressure is required for penetration of the stylet

Method II

After osteotomy of the base of the transverse process of the involved vertebra has been performed, an alternate method of approach to the vertebral body can be carried out in the following manner The transverse process is retracted sufficiently, in conjunction with slight depression of the adjacent rib, to expose the junction of the pedicle and body The trephine is used to penetrate this junction at an angle of 45 degrees toward the centrum, and material is similarly removed with a curette (Fig 3,*C*)

LUMBAR VERTEBRAE

The approach to the lumbar vertebral bodies is easier than that to the thoracic bodies, both because the vertebrae and their processes are larger and because of the sagittal or anteroposterior arrangement of the facets Any one of the following three methods may be selected for penetration of the bodies of the lumbar vertebrae

Method I

A paravertebral incision is made, directly over the articular facet of the vertebral body under consideration The articular facets are located and denuded Penetration into the isthmus, pedicle, and body is made through the superior articular process After this process has been located, the ascending facet will indicate the body of the lumbar vertebra to be operated upon Towel clips are applied to the ends of the spinous processes of the adjacent vertebrae, and the exposed facet articulation is identified by alternate pushing and pulling on the two clips A marker is inserted into the joint space of the articular facet and a trephine, five-sixteenths of an inch in diameter, is slipped over the marker (Fig 4,*A*) The cartilaginous plates of the articular facet are completely gouged when the trephine has penetrated for a distance of one-half inch (Fig 4,*B*)

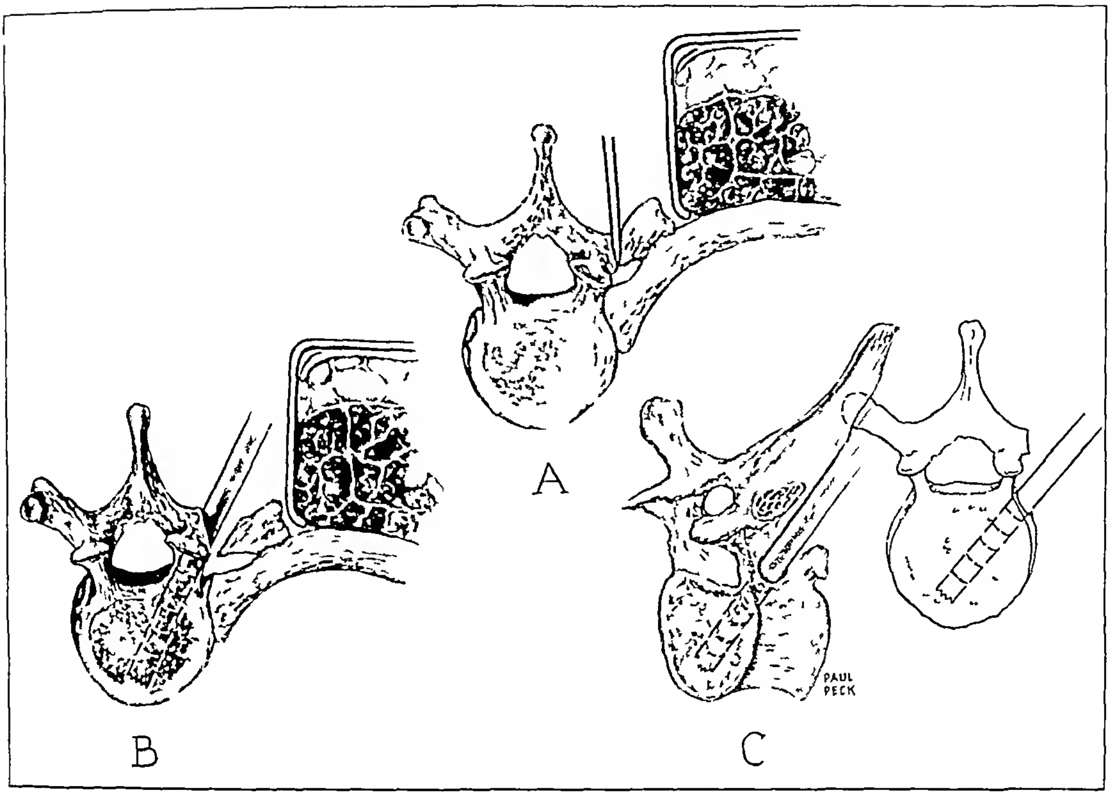

FIG 3

A Transverse osteotomy at the base of the thoracic transverse process
B Trephine through the fenestra of the isthmus, into the pedicle and body
C Trephine inserted into the body, at junction of pedicle

The two buttons of bone facing the marker are removed (Fig 4,*1*), the articular cartilage of the apophyseal joint is found to be sandwiched between them A smaller trephine is inserted into the fenestra and is carried downward, usually by its own weight, for three-quarters of an inch With slight twisting, the trephine is manipulated within the medullary

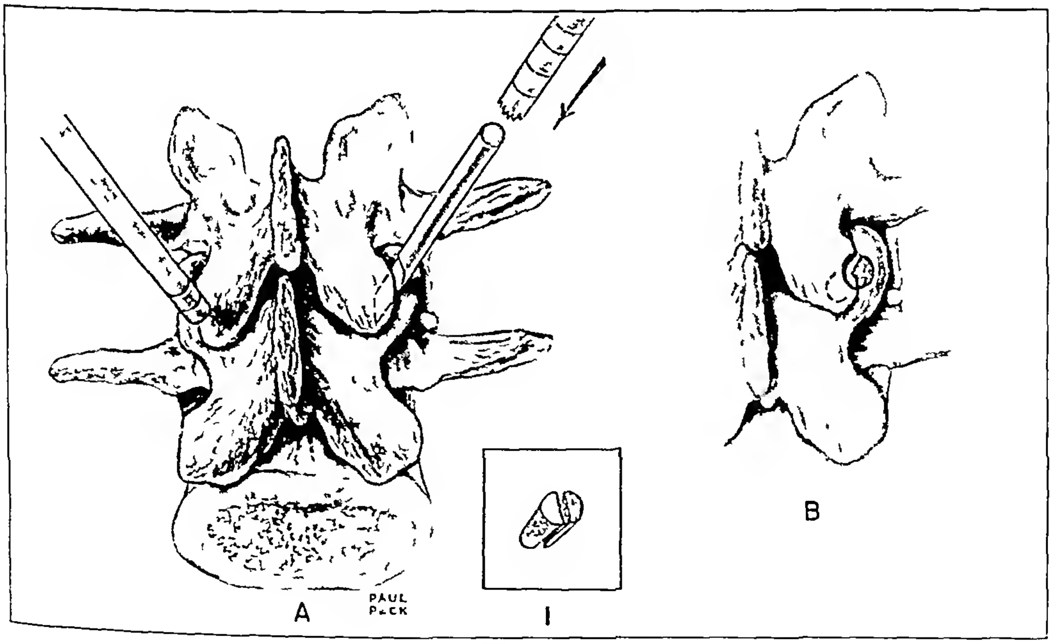

FIG 4

A Marker is inserted into the articular facet Trephine is slipped over the marker
B The bored leaves of the articular facet, with a channel of cancellous bone
1 Inset shows the two buttons of bone removed

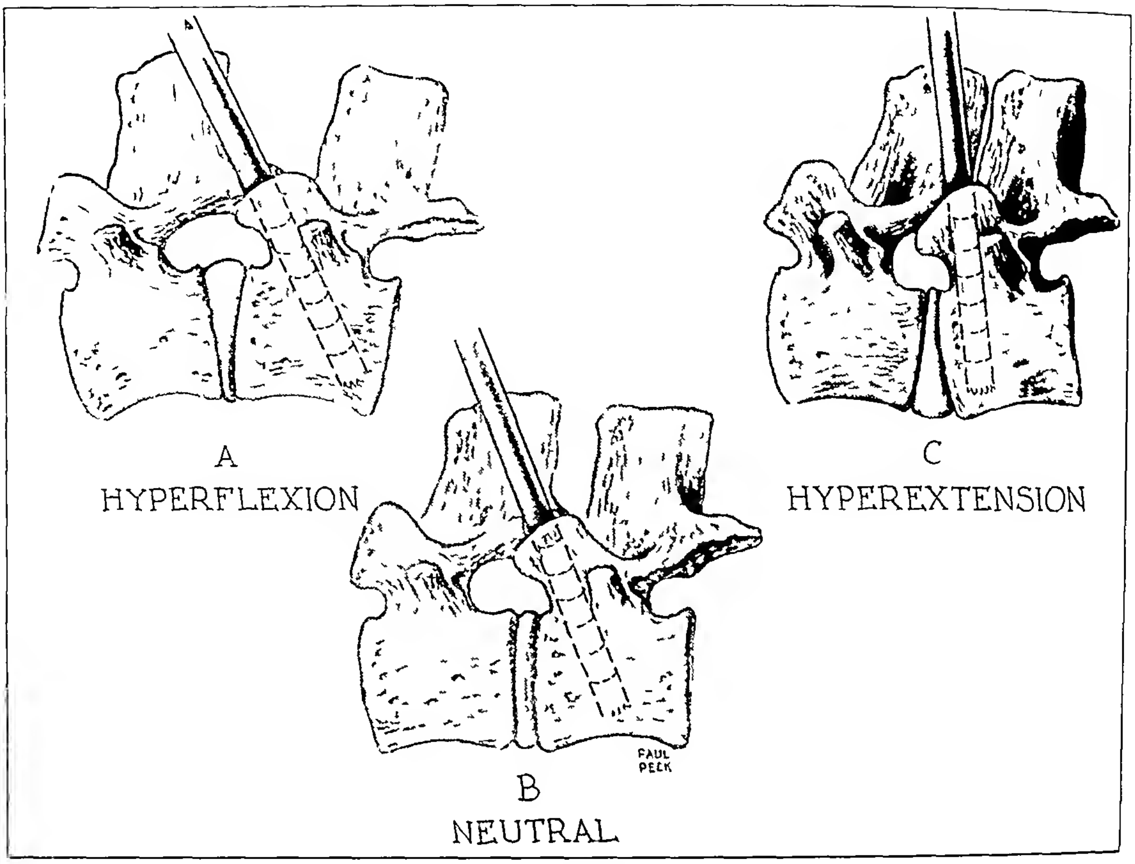

FIG. 5

The position of the spine on the operating table will determine the direction of the trephine.

portion of the pedicle. After each minute progression, the material in the trephine should be examined to be sure that cancellous bone is present. If the cortical bone is being skimmed, the operator can detect this by noting the deflection of the instrument. The body is penetrated in most instances when the trephine has been inserted for one inch. Samples of material for biopsy and cultures can be removed with the trephine through this opening (Fig. 6,*A*). Sufficient material for diagnosis can be obtained by simple curettement of the body. The stylet may be used instead of the trephine for penetration through the fenestra into the isthmus, pedicle, and body. In the lumbar spine, as in the thoracic region, the medullary bone extends within a channel from the isthmus, through the pedicle, and into the body.

After completion of the biopsy, the articular facets[1] are either locked by 90-degree rotation of the removed buttons of bone, or they are reinforced by use of a part of the spinous process, transverse process, or preferably, the iliac bone (Fig. 6,*B*). By inserting a larger trephine through a small incision over the ilium, the necessary peg of bone can be obtained.

Method II

The approach through the transverse processes is carried out by extending the exposure through the articular facet (Method I), and retracting the muscles from the base of the transverse process of the vertebral body involved. An osteotomy is performed at the base of the process, after it has been bared at the posterior surface and the laminal plate has been exposed (Fig. 7,*A*). A greenstick osteotomy of the transverse process is done and it is depressed, but not removed from its bed. A fenestra with exposure of the isthmus is obtained in this manner, and the operation can be continued either by use of a trephine through the isthmus into the pedicle and the body, or by penetration with the trephine stylet (Fig. 7,*B*). Curettement of the body can then be carried out.

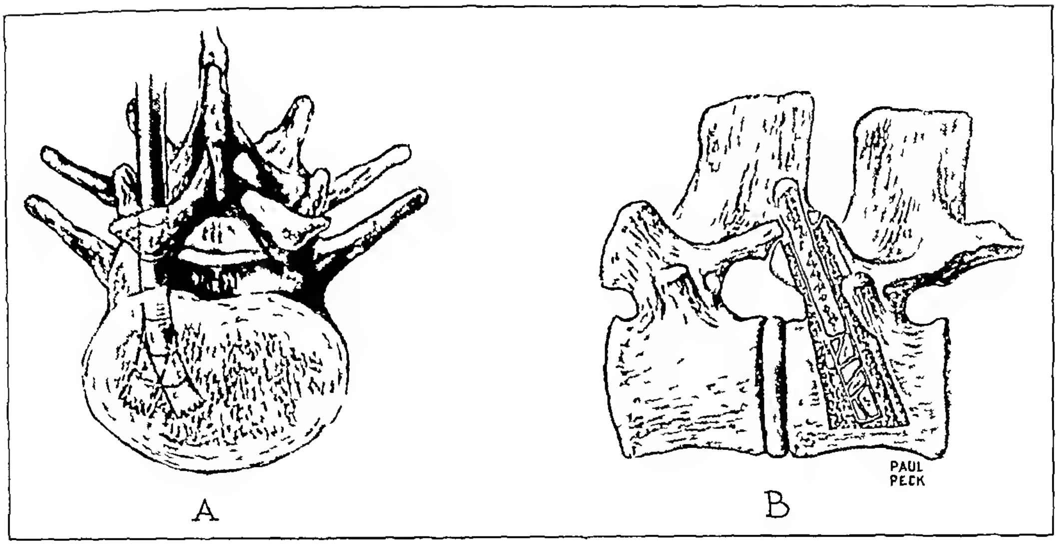

FIG 6

A The curved trephine is used to indicate the circumference of penetration of the body by the curette

B Iliac bone graft, used to reinforce the articular facets, is fixed into the pedicle

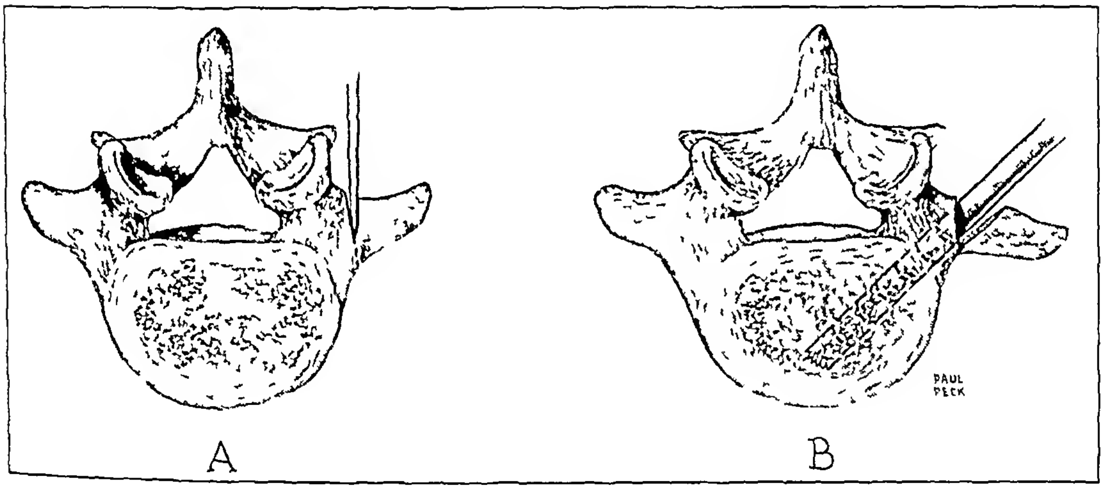

FIG 7

A Greenstick transverse osteotomy of lumbar transverse process

B Trephine inserted into the fenestra, pedicle, and body

Method III

This method is in reality a continuation of Method II The osteotomy is performed at the base of the transverse process of the involved vertebra The transverse process is not removed from its bed, but is merely depressed, so that, by blunt periosteal stripping, the entire pedicle can be exposed at its lateral margin The point of junction of the pedicle and the body of the vertebra is selected as the site of penetration of the trephine into the body

SUMMARY

Five methods of direct approach to the thoracic and lumbar vertebral bodies have been presented In each instance, the surgeon should select that procedure which is safest for the particular vertebral body involved By approaching the vertebral body directly through definite bone channels which can be readily exposed, the selected portions of the body contents are made available for diagnosis and subsequent therapy These methods are particularly valuable in those cases in which the lesion is confined to the vertebral

body, and no other sources of biopsy or culture material are available upon which to base a diagnosis Moreover, the direct approach facilitates the introduction of penicillin streptomycin, or other medication into the vertebral body

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POSTERIOR DISLOCATION OF THE STERNOCLAVICULAR JOINT

REPORT OF A CASE

BY WALTER A GUNTHER, M D, KNOXVILLE, TENNESSEE

From the Penn Clinic, Knoxville

Dislocation of the clavicle at its sternal end is relatively rare, as compared with acromioclavicular dislocation Of the three main types—anterior, superior, and posterior—the anterior is by far the most common Not more than thirty cases of the retrosternal variety have been reported in the literature

FIG 1

Oblique view of left sternoclavicular joint before reduction

The following report presents a case treated successfully by manipulative reduction

A fifteen-year-old white American boy reported to the emergency room of the hospital on November 13 1948, complaining of pain in the chest He walked slightly hunched over, and held the left forearm in his right hand Although in pain, he was not dyspnoeic or particularly apprehensive He stated that two hours

Fig 2
Oblique view after reduction

earlier, while engaged in a sand-lot football game, he had hurled his 135 pounds at an opponent of 190 pounds in a "body block" At the moment of impact he had turned the left shoulder toward the opposing player and had received the full force of the latter's charge on the posterior and lateral aspects of his left shoulder He was knocked to the ground and felt instant pain in the region of the sternum

On physical examination, a depression was felt at the sternal end of the left clavicle, at the spot where the slightly bulbous end of the clavicle may usually be palpated There was some swelling over this point and it was extremely tender to the touch There was no evidence of dyspnoea or dysphagia No abnormal discoloration was present, nor evidence of air under the skin Examination of the left upper extremity revealed no signs of peripheral-nerve damage or of circulatory changes Roentgenograms of the chest wall in right and left oblique views showed the sternal end of the left clavicle to be displaced behind the sternum The actual overlap, without compensation for distortion in the film, was seven-eighths of an inch

The patient was told that closed reduction of the dislocation should be done without delay He refused treatment and left the hospital, carrying the left arm in a sling Two days later he reappeared, the pain and swelling in this region having increased

After suitable preparation, intravenous pentothal was administered, and an unsuccessful effort was made to reduce the dislocation by strong upward and outward traction on the left arm, as well as backward pressure on the shoulder The anterior aspect of the chest wall was then prepared as for surgery, and the points of a towel clamp were introduced through the skin at the left sternoclavicular joint The clavicle was seized firmly, as close to the sternal end as possible Strong traction was made on the clamp, while the previous manipulations were repeated by assistants With a click, the clavicle moved back into its normal relationship to the sternum Roentgenograms (Fig 2) showed that the right and left sides were symmetrical The sternal end of the clavicle could be palpated in its proper position

While both shoulders were held back, a well-padded plaster-of-Paris figure-of-eight dressing was applied to the shoulder girdle The boy wore this for one month, and was ambulatory At the end of that time the swelling had subsided, and the bony landmarks were normal in position and painless to palpation He had full motion of the left shoulder joint

News Notes

The American Orthopaedic Association will hold its Annual Meeting at Virginia Beach, Virginia, May 23, 24, 25, and 26, 1950

The Seventeenth Annual Meeting of **The American Academy of Orthopaedic Surgeons** will be held in New York City, February 11–16, 1950, with headquarters at the Waldorf-Astoria

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The Seventy-seventh Annual Meeting of the **American Public Health Association** will be held in New York City, October 24–28 Meetings of related organizations will take place concurrently The Hotels Statler and New Yorker are joint headquarters

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"Achieving Goals for the Handicapped" will be the theme of the Annual Convention of the National Society **for Crippled Children and Adults,** to be held November 7, 8, 9, and 10, at the Hotel Commodore in New York

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Alpha Chi Omega, national women's sorority, has voted an additional grant of $10,000 to the **National Society for Crippled Children and Adults,** to continue a jointly sponsored scholarship program for training much needed professional personnel to work with the cerebral palsied The $10,000, in addition to $15,000 already granted, will aid greatly in carrying the program through the next two years

Since the first awards were made in 1948, more than twenty-five scholarship grants have been provided to qualified physicians, physical therapists, and other specialists When they have completed their scholarship study these professional workers assist the National Society's 2,000 state and local units throughout the United States Hawaii, and Alaska, as well as other public and private agencies, in providing increased services for individuals with cerebral palsy

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On July 6, 1949, a Testimonial Dinner was given to Dr Leo Mayer, President of the **Federation of the Handicapped,** in honor of his sixty-fifth birthday, by his grateful friends and patients who have established the Dr Leo Mayer Endowment Fund to perpetuate his work through the Federation, in establishing an institution where the handicapped are employed in a work-training program, are paid a wage, and produce merchandise which is sold nation-wide The Federation is a rehabilitation agency where professional guidance is given and physical therapy practised under actual working conditions Jobs are found for those who are made ready for them Socially, regular entertainments, educational lectures, hobby clubs, and forums are conducted In a word, the Federation provides a complete and thoroughly up-to-date rehabilitation program Dr Mayer has for the past five years served as President of the Federation

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The National Council of the **Kappa Delta Sorority** has inaugurated a prize of one thousand dollars to be given annually by **The American Academy of Orthopaedic Surgeons,** for the best research in orthopaedic surgery, performed during the year by an individual in the United States The first award, for the year 1949, will be announced at the Seventeenth Annual Meeting of the Academy in New York, February 11, 1950 Those wishing to compete for this prize may secure further information from the Chairman of the Award Committee for 1949, Dr Walter Stuck, 1426 Nix Professional Building, San Antonio, Texas

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LETTER TO THE EDITOR

Orthopaedic surgeons who have bone banks available realize the tremendous advantage of obtaining suitable fresh cadaver material To obtain the consent for this, one must carry out an educational program A plan has been well worked out at a national level by the ophthalmologists in setting up eye bank

In many ways the cooperation of the institutions having bone banks may prove of inestimable value An explanatory pamphlet could be published and distributed A uniform consent blank could be used Developments of technique could be shared

Walter P Blount, M D
324 East Wisconsin Ave
Milwaukee 2, Wisconsin

Book Reviews

ESSENTIALS OF ORTHOPAEDICS Philip Wiles, M S (Lond), F R C S (Eng), F A C S London, J and A Churchill, Ltd , 42 shillings net, Philadelphia, The Blakiston Company, 1949 $10 00

In this outstanding volume of 475 pages, Mr Wiles has concisely and clearly explained the present-day concepts of "the physiological and pathological basis of orthopaedics" and their "application to diagnosis and treatment"

The book offers the graduate who is entering upon his surgical training, the undergraduate who requires classified information, and the general practitioner a ready means of finding himself in the vast field of orthopaedic surgery and of proceeding with his work with assurance that he has a sound foundation upon which to build To teachers of orthopaedics the book will be invaluable More than these, the mature surgeon may find in the *Essentials* much that will enable him to revise and broaden his viewpoint

Logically, the first chapter is devoted to general considerations of the mechanics underlying the functions of the weight-bearing joints The effects of postural and mechanical faults are stressed, and the importance of strain is thus emphasized at the outset In the ensuing chapters the arrangement is regional to assist the student with diagnosis and to meet his need for information on pathology and treatment, classified in an orderly manner Treatment requiring less highly specialized knowledge is described in detail, operative and other methods are given only in general terms The importance of the patient's cooperation is stressed throughout, and prognosis is discussed Separate chapters are devoted to "Pyogenic Infection", "Tuberculosis", "Chronic Arthritis", "Tumours of Bone", "Diseases and Congenital Defects of Bone", and "Diseases of the Nervous System"

While the essentials have been presented largely from the British viewpoint, the author has drawn freely from practices in other countries This is especially true of American methods, from which he seems to have, in most instances, selected the best

The book reflects the high standards maintained in British publishing The author's presentation of the subject is thorough-going, but always concise and practical The book in every way fulfills its high purpose and should long enjoy wide acceptance The excellent illustrations include seven color plates and 365 text figures

INSTRUCTIONAL COURSE LECTURES The American Academy of Orthopaedic Surgeons Walter P Blount, M D , Editor Ann Arbor, Michigan, J W Edwards, 1949 $7 50

This volume of lectures, given in the Instructional Courses of The American Academy of Orthopaedic Surgeons in 1948, is the fifth in a series begun in 1943 The courses are primarily "refresher", yet the reader of the *Lectures* will find he is kept abreast of the newer developments in the specialty in the wide range of subjects presented Emphasis is placed on the practical The subjects covered are those which the Program Committee found to be in greatest demand

The book is composed of fourteen chapters, each containing one or more carefully edited and comprehensive lectures on the following subjects "Vascular Tumors of Bone", "Vascular Phenomena", "Plastic and Hand Surgery", "Internal Fixation of Fractures", "Surgical Tuberculosis in Children", "Acute Infectious Hematogenous Osteomyelitis", "Painful Hips in Children", "Practical Foot Problems", "Treatment of Congenital Club Feet", "Surgical Approaches" (to the upper and lower extremities), "Muscle Physiology", "The Surgical Treatment of Poliomyelitis", "Scoliosis", and "Low Back Pain"

As in the preceding years of the Courses, the 1948 faculty is composed of a distinguished group of surgeons who have excellently presented their subjects The volume is well edited and prepared, for which great credit is due Dr Blount The illustrations are profuse and, in general, of good quality Students, teachers, and practitioners of orthopaedic surgery will find the 1948 *Lectures* of great value

The preceding volumes of the *Lectures* were edited by Dr J E M Thomson, who was so largely responsible for the inception and successful development of the Instructional Courses These volumes reflect much that is important in the development of the art and practice of American orthopaedic surgery during the preceding five years The first two volumes are in large part directed toward the problems of war-injury and reconstructive surgery, the third and fourth, which are complementary, deal with civilian surgery Copies of these volumes are also available for those who wish to own the complete set

THE PARATHYROID GLANDS AND METABOLIC BONE DISEASE SELECTED STUDIES Fuller Albright, A B , M D , and Edward C Reifenstein, Jr , A B , M D , F A C P Baltimore, The Williams and Wilkins Company, 1948 $8 00

Research studies on calcium metabolism, carried out on the Metabolic Ward of the Massachusetts General Hospital during a period of twenty-four years by many different investigators, form the basis of the

material presented by Dr Albright and Dr Reifenstein in their outstanding contribution The advance made by the authors and by those associates, past and present, upon whose studies they have drawn, are presented in a readable style, of sufficient clarity so that the book will be useful to students, yet on the basis of such experience as to make it valuable to physicians, particularly those interested in orthopaedic problems The text is amplified by many case reports and by excellent photographs, charts, and reproductions of roentgenograms, illustrative of the conditions under consideration

In addition to chapters on the parathyroid glands, hypoparathyroidism, and hyperparathyroidism, there is discussion of metabolic bone diseases, osteoporosis, osteomalacia, polyostotic fibrous dysplasia, and Paget's disease

The authors state in their Preface " we are not content merely to present data, we attempt, when possible, to develop an hypothesis upon which to hang the observations The hypotheses—it almost follow —are subject to change without notice " Thus not only does the reader have a presentation based upo work of exceptional value, but he is given the mental stimulation of an approach which invites intere in an ever-broadening field

SURGERY OF THE HAND Ed 2 Sterling Bunnell, M D Philadelphia, J B Lippincott Company, 1949 $16 0(

Surgery of the Hand, published in 1944, received high praise as a book of outstanding value Dr Bunnel has now revised and rewritten this book, incorporating his experience during the past five years

Changes have been made in many chapters The author has developed many ingenious splints, and thes are included in the section under "Active Splinting" New sections have been added in the chapters "Ski and Flexion Contractures", "Bones", and "Joints" A new section on "Occupational Therapy for Crippl Hands" has been included

However, the greatest changes in the new edition are in Part Three, in the chapters on "Injuri of the Hand", and "Infections of the Hand" The many developments in the field of reconstructive surger of the hand are reflected in this new book

As Consultant in Hand Surgery to the Surgeon General of the United States Army, Dr Bunnell wa closely in touch with the Hand Service in each of nine Army General Hospitals Through these variou Hospitals, he had opportunity to watch the reconstruction of about 20,000 hands The experience in thes Army Hospitals is shared with the readers of this new edition through the conclusions which he has reached as to the procedures to be followed in the treatment of injured hands His definite convictions as to the methods of choice in various conditions are presented from the point of view of a teacher who has had unusual experiences which he wishes to share with his students and those who have had fewer opportunities to perfect themselves in this field of surgery

As the interest in surgery of the hand has increased in the last few years, particularly through the formation of the American Society for Surgery of the Hand, of which Dr Bunnell was the first President, many surgeons have been called upon to treat hand injuries

Dr Bunnell's book will prove a valuable reference to all surgeons confronted with hand conditions, in the treatment of which so great care in the selection of the best procedure is required

The book is attractively presented, the illustrations are excellent It is a book which most surgeons will wish to own

FUSS UND BEIN IHRE ERKRANKUNGEN UND DEREN BEHANDLUNG (Affections of the Foot and Leg and Their Treatment) 4 Auflage Prof Georg Hohmann Munchen, J F Bergmann, 1948

This new edition of the well-known text by Professor Hohmann will be welcomed by those who have used earlier editions, as well as by those who have only indirectly known its worth

The first edition of this book appeared in 1923, and this, as well as the two editions which followed, were dedicated by the author to his teacher in orthopaedic surgery, Geheimrat Fritz Lange Recognizing the importance of his instruction in the natural sciences, in languages, and in other subjects preparatory to hi profession, as well as the contribution of other branches of medicine to his special field, he has dedicated this fourth edition to his teachers, among whom Fritz Lange holds first place

Beginning with the form, structure, and function of the normal foot, the author takes up the variou deviations from the normal,—congenital and acquired deformities of the lower extremity, their etiology, prevention, and treatment, as well as diseases affecting the joints, nerves, muscles, and bones, their diag nosis and treatment, and their possible effect on the function of the extremity Trauma is also discussed especially injuries received in sports

The excellent bibliography, classified under the different affections discussed, will be helpful to those who wish to locate the earlier references to these various conditions It contains only a few references to article appearing during the War, and obviously was prepared before the author had access to the British and American literature of the past ten years

This book contains more than twice the number of text pages of the earlier editions The number of il

lustrations has been increased to 150 and they are more attractively presented than in the previous editions Both author and publisher are to be congratulated upon this revision, made at a time when its preparation must have been attended with great difficulties

BRITISH SURGICAL PRACTICE Volume 5 Edited by Sir Ernest Rock Carling, F R C S, F R C P, and J Paterson Ross, M S, F R C S London, Butterworth and Company, Ltd, 60 shillings (25 pounds for the set), St Louis, C V Mosby Company, 1948 $15 00 ($125 00 for the set)

The Editors of *British Surgical Practice*, who have been releasing units of this eight-volume set at intervals since the first number appeared, late in 1947, have now completed Volume 5 Proceeding with the established alphabetical arrangement, this work begins with Hodgkin's disease and concludes with lymphogranuloma inguinale In this portion of the alphabet are contained material on injuries and many sections dealing with joint disorders, including caisson disease, acute infections of the joints, internal derangements of the knee joint, and joint tuberculosis Thus the present volume is of special interest to orthopaedic surgeons

Each volume in the series follows the same general pattern so that, for most conditions, the etiology, anatomy, pathological findings, clinical picture, differential diagnosis, treatment, results, and prognosis are presented Each section has been carefully prepared by an authoritative worker in the field, and the series is living up to its early promise of being a valuable aid to the surgeon

HOSPITAL TRENDS AND DEVELOPMENTS, 1940 TO 1946 Edited by Arthur C Bachmeyer, M D, and Gerhard Hartman, Ph D New York, The Commonwealth Fund, 1948 $5 50

This book is a composite reflection of numerous writers in the hospital and public-health field, given cohesion and form by arrangement according to the various phases of an administrator's activities and interests (Incidentally, mention of hospitals and public health together is itself an expression of one trend) The authors' principal problems were to decide what the trends and noteworthy developments were and to select the articles in which they are set forth most clearly Presumably they also exercised the editorial blue pencil here and there, but so skillfully that the marks do not show

They have done their work well This could have been anticipated, as Dr Bachmeyer is dean of the hospital administrators in the Chicago region, while Dr Hartman is developing his skill as an administrator upon a background of several years of educational activity as Secretary of the American College of Hospital Administrators

Just what interest bone and joint surgeons will take in a book of this character is not clear, except that they all need hospitals in which to operate There may be a few, however, who would like to get some of the background of today's most argued medical question as it applies to hospitals This comes in the first part of the book The rest will probably be attractive mostly to hospital administrators, for whom the book was really intended Students of this specialty will find it interesting and instructive, a good adjunct to their seminars and field trips Practitioners are likely to find some of the articles familiar, but they are worth reading again There is a chance of discovering some things not seen before, as the authors have gleaned beyond the field ordinarily reaped by a reader of strictly hospital publications

As the title suggests, this is, for the most part, a series of explanations, discussions, and advice, rather than the sort of detailed direction for setting up departments and putting them into operation which made Dr MacEachern's textbook so useful However, most of the things a hospital administrator does and thinks about in his multiple role of architect, accountant, attorney, clergyman, credit expert, economist, educator, engineer, laundryman, publicist, restauranteur, crystal gazer, and sometimes physician, are represented by at least one article

As samples, take this reviewer's favorite exposition of the proper duties and the value of a medical social-service department, the discussion of work suitable for nurse aides, and the late Dr Joe Clemmons' account of how he saved the Roosevelt Hospital a lot of money by doing over his laundry with new machinery This array of writers exhibit many styles with only the fictional narrative form missing, but each of them has treated his subject with the care that only personal interest in it could produce

A book of this kind should not be read rapidly He who takes it a little at a time, stopping to digest each bite before taking the next, will find himself nourished and sustained

DEEP MASSAGE AND MANIPULATION ILLUSTRATED Ed 3 James Cyriax, M D, B Ch (Cantab) London, Hamish Hamilton, Ltd, 17 shillings, 6 pence, New York, Paul B Hoeber, Inc, 1948 $5 00

This book is written to instruct student and graduate physical therapists in the technique of massage The type of massage described is considered more or less specific for the condition commonly known as "fibrositis" Photographs show the position of the patient and of the therapist's hands for each area of the body The description accompanying each plate serves as a detailed prescription for the technician

Most physiatrists in this country would doubtless emphasize the combined use of other agents in their prescriptions, such as heat in various forms and active exercise The amount of pressure, the range of movement, and the duration of the treatment are still only approximately indicated, and are part of the art of physical therapy Physicians should be interested in these methods of treatment and will be intrigued by the good results almost uniformly reported Acceptance of the diagnosis of "fibromyositis" is essential for utilization of these procedures

Those familiar with the previous edition of this book will find little change other than a few more photographs, these are uniformly of good quality, as is the type and paper

FRACTURES AND ORTHOPAEDIC SURGERY FOR NURSES AND MASSEUSES Ed 2 Arthur Naylor, Ch M, M B M Sc (Sheff), F R C S (Eng), F R C S (Edin) Edinburgh, E and S Livingstone, Ltd, 17 shilling, 6 pence, Baltimore, The Williams and Wilkins Company, 1948 $5 00

This book of 296 pages, divided into fourteen short chapters, is intended to introduce nurses and masseuses to the more common fractures and orthopaedic conditions It is brief and concise, and contains many illustrations of apparatus, instruments, techniques, and clinical cases which would be helpful for students and nurses

This publication, however, does not differ from the many small textbooks on fractures and orthopaedic conditions which have preceded it As its readers will be chiefly nurses and masseuses, the approach to fractures and orthopaedic problems is presented from their point of view However, the book could have been made more useful to nurses by placing more emphasis upon specific problems of nursing care, and to masseuses by more detailed instruction in the problem of rehabilitation as related to each type of injury Space is allotted for this, but it seems inadequate for a book of its type

The reader will receive a general, but limited, review of the recognition and treatment of orthopaedic conditions and fractures

FINAL RESULTS OF OSTEOSYNTHESIS OF FRACTURES OF THE FEMORAL NECK AD MODUM SVEN JOHANSSON A STUDY OF A TEN-YEAR MATERIAL Gunnar Oden *Acta Chirurgica Scandinavica*, 96 Supplementum 131, 1947

The author analyzes the results of treatment of 314 fractures of the upper portion of the femur, using a cannulated Smith-Petersen nail, inserted as fixation with roentgenographic control This group comprises 59 per cent of all upper femoral fractures treated at the Sahlgren Hospital, Gothenburg, from 1932 to 1941 They represent a thorough reinvestigation of the results obtained by Sven Johansson

The 314 fractures of the femoral neck were distributed as follows 248 varus fractures, 44 valgus fractures, 18 intertrochanteric fractures, and 4 pertrochanteric fractures

Traction, with the affected leg in external rotation and extension, was used for about a week before operation Local anaesthesia with ether was used generally and, in most cases, reduction was achieved by simple internal rotation just before fixation When difficulty of reduction was encountered, ordinary traction was resumed for a week or so, and repeated attempts at manipulative reductions were avoided There was a mortality of 8 per cent

Most of the patients were kept in bed for four weeks after operation Redislocation after reduction occurred in 66 of the 314 cases A follow-up study of the whole group was not possible, but, from his study of those cases available, the author inferred that valgus fractures heal easily, and that, among varus fractures, those fixed in valgus are least likely to lose position, and those fixed in varus are most likely to lose position

Oden felt that, in addition to the circumstance of position of fixation, technical deficiencies of the operative procedure were most important in producing loss of position, and that early weight-bearing was not the cause of loss of position

Re-nailing was done in thirty-eight cases Of those available for follow-up, non-union, loss of position and head necrosis were much more frequent than in the entire group Bone-grafting with re-nailing was employed only twice, and each time *un*successfully

Of the whole group, 144 neck fractures were submitted to re-examination at least three years after nailing Seventy per cent were considered to have had good results, 10 per cent were "less good", and 20 per cent were bad

Pseudarthrosis occurred in 10 8 per cent Some head necrosis was present in 38 4 per cent, with joint deformity in nine out of ten of these, 24 7 per cent had neck resorption Slipping of the nail was evident in 44 per cent

The author considered that necrosis of the head, the most frequent cause of bad results, was a vascular phenomenon not influenced by the presence of a metal nail Swedish stainless-steel nails, used during the latter five years of the period, were non-corrosive and satisfactorily strong

The observation was made that symptoms from arthrosis following head necrosis often diminished greatly after two or three years

AFFECTIONS MÉDICALES ET CHIRURGICALES DU PIED Raphaël Massart Paris, G Doin et C^ie^, 1948 470 francs

The author's intention to give a simple description of lesions of the foot, mainly for general practitioners, is well accomplished in this 150-page book with forty-four drawings Each of its thirteen chapters contains a complete and vivid description of foot conditions

The author should particularly be commended for allotting considerable space to "minor", but important, foot problems, such as corns and plantar warts His painstaking description of the corn, however, fails to bring out the importance of the bony prominence superficial to which the corn usually is formed Consequently, smoothening of the bone by removal of these prominences with primary closure of the wound would seem to be preferable to the incision over the corn down to the bone which he leaves open to granulate

Calcaneal spurs are blamed for symptoms in painful heel, although the author admits the existence of painful heel due to some "mysterious cause" without the presence of spur His emphasis upon the removal of spurs may be somewhat too radical, as the majority of these cases are relieved by padding and plates

Intermittent claudication, one of the most important diagnostic features of arterial occlusion, is not mentioned He speaks only of gangrene of three types (1) endarteritis sclerotica, (2) thrombo-angiitis obliterans, and (3) diabetic endarteritis, without stating that in the majority of these cases the course is quite benign without even the formation of an ulceration

Congenital division and fracture of the sesamoids of the big toe are not differentiated, and removal of the sesamoids advocated by the author may be avoided in most cases

The author is justly opposed to the Hueter-Mayo operation for hallux valgus, as it deprives the foot of its important medial weight-bearing point He advocates Hohman's type of wedge resection of the first metatarsal neck, combined with passing a strip of fascia lata surrounding in garter-like fashion the metatarsal necks This operation he performs in two stages

Similar passing of the fascia lata or a kangaroo tendon around the metatarsal necks is advised as the best procedure for treatment of Morton's type of neuralgia The existence of plantar neuroma, described by American authors, is mentioned simply in a footnote

Club-foot is held to be a consequence of a vicious position in the uterus Gradual manipulation without anaesthesia, or *redressement forcé* with anaesthesia, both followed by immobilization, have given the author good results He obviously has no knowledge of Kite's method, and mentions Denis Browne splints only in a footnote

A good morphological description of different forms of flat-foot is given, but no theories as to its etiology are offered Corrective plaster casts or manipulation under anaesthesia are used, followed by immobilization in plaster, together with general treatment (calcium phosphate, arsenic, and hypophyseal extract) Whitman's type of plates are advised Among many operative procedures for flat-foot, the author obtains the best results by simply resecting the head of the talus

In tuberculosis of the talus, early and complete astragalectomy, before the formation of sinuses, is strongly advocated Tuberculosis of the tarsal bones may be treated conservatively in children, most adults eventually require amputation

The author has been unable to confirm the good results published in America following fusion of the ankle, with the use of tibial grafts, and is opposed to this method

In the last chapter, on amputations of the foot, Ricard's operation, consisting of disarticulation through the Chopart line combined with astragalectomy, is preferred to the Syme amputation as it preserves the weight-bearing heel

On the whole, the book is brief and comprehensive It reflects a wide and well-digested experience on the part of the author, and should form a significant addition to the libraries of French-speaking general practitioners

CLINICAL ASPECTS AND TREATMENT OF SURGICAL INFECTIONS Frank Lamont Meleney, M D Philadelphia, W B Saunders Company, 1949 $12 00

This is a fitting companion-piece to the author's *Treatise on Surgical Infections*, published in 1948 The earlier volume dealt with the fundamental principles underlying the entrance and spread of bacteria in the body, and the mechanism of defenses of the body against infection The present volume deals with the surgical and chemotherapeutic measures which may be utilized to control infection

The eighteen chapters are arranged to cover infections of every anatomical area, and are illustrated by numerous well-written case reports from the records of the Columbia-Presbyterian Medical Center There are also 276 well-chosen illustrations An excellent bibliography follows each chapter

Dr Meleney has enlisted the aid of his former residents to cover certain subjects Thus John S Lockwood has written the chapter on "Physiological Consideration in Surgical Infection", Harold D Harvey has contributed the chapter on "Surgical Infection of the Peritoneum", and a chapter on "[illegible] ons in War Wounds" is divided between Alfred B Longacre and William R Sandusky

The treatment exemplified covers both the period before the advent of the sulf [illegible] ent A detailed account of the usefulness of penicillin, streptomycin, [illegible] is gi[illegible]

priate, and the course of an infection is compared by means of case reports as it occurred with each method of treatment

This volume contains the latest information on surgical infections, and will probably remain authoritative for an indefinite period of time, subject to newer forms of therapy No surgeon, general practitioner, or medical library can afford to be without it

MALADIES DU SQUELETTE (Diseases of the Skeleton) Lucien Leger, R Ducroquet, et Henry Leger Paris Masson et C^ie^, 1949 1,200 francs

The title of the book may suggest a treatise on diseases of the skeleton in general, however, the text actually consists of a few of the important, but less known, entities affecting the skeleton Albright's syndrome and affections which may be classified in this group, isolated xanthomatoses, lipoid granuloma without cranio-hypophyseal involvement, eosinophilic granuloma of bone, osseous lesions of von Recklinghausen's neurofibromatosis, melorheostosis, Milkman's disease, essential osteolysis, and myeloma are the subjects of this book

The choice of these pathological entities was not accidental Although some of them are obviously not interrelated, others have doubtless a common anatomicopathological basis Thus, alongside the symptomatic group of Hand-Schuller-Christian diseases may be placed the xanthomatoses Albright's syndrome may, perhaps, be found related to a series of osseous involvements associated with cutaneous dyschromia, presenting a transition to the bone manifestation of von Recklinghausen's neurofibromatosis

The organization of the book is excellent, it is replete with useful information, many illustrations, and followed-up case histories, and represents a complete, lucid, and live analysis and description of these pathological conditions It has extensive bibliographical references

The orthopaedic surgeon who reads French will find it a valuable addition to his library

SURFACE AND RADIOLOGICAL ANATOMY FOR STUDENTS AND GENERAL PRACTITIONERS Ed 3 A B Appleton, M A , M D (Cantab), W J Hamilton, M D , D Sc , F R S E , and G Simon, M D , B Ch , D M R E (Cantab) Cambridge, England, W Heffer and Sons, Ltd , Baltimore, The Williams and Wilkins Company, 1949 $9 00

In this, the third edition of *Surface and Radiological Anatomy*, the text has been revised and new plates have been introduced to bring the work up to date The authors have added the roentgenographic approach to the usual study of anatomy By extensive use of illustrations, they have coordinated roentgenographic anatomy with those features which can be determined by external examination, as well as with the detail which can be determined only by dissection Proper emphasis is placed upon individual, anatomical, functional, and postural variations which alter the position of organs in relation to surface and other landmarks Thus an excellent contrast is obtained between the living subject and the cadaver

The text is well arranged and the type is well chosen The first section deals with "General Anatomy and Methods" Subsequent sections are devoted to "The Upper Limb", "The Chest and Back", "Abdomen", "Head and Neck", "The Vertebral Column", and "The Lower Limb" The Appendix contains tables with data on ossification and on segmental innervation of muscles A fairly complete index is included

The text includes brief sketches of bones, muscles, joints, nerves, vessels, and organ-structure relationship and action, with correlation of superficial and roentgenographic landmarks Interesting technique an interpreted, and so are hints of occasional pathological processes, to add interest

The illustrations consist of photographs of live models, frequently coupled with a schematic anatomical dissection or with superimposed diagrams The descriptive captions are excellent The terminology is simplified and is that in common usage The roentgenograms (the authors prefer the term skiagram) are numerous demonstrating the positions and structures under discussion The joint studies are excellent, and are correlated with the text through a description of muscle action Most of the osteology is presented by the roentgenographic method, and includes reference to and illustrations of bone and joint development Diaphragmatic action is demonstrated, as are the organs which can be outlined by contrast media This introduces under suitable headings, examples of interesting roentgenographic techniques, such as tomography, kymography, bronchography with studies of the bronchial and lung divisions, myelography, encephalography, and angiography, as well as the more common roentgenographic diagnostic procedures

The authors seem a little modest in designating this book "For Students and General Practitioners" Its concise and systematic fashion of presentation makes for easy reference In the 330 pages are incorporated a mass of related information which could be put to use by most physicians

CONFERENCE ON POST-GRADUATE EDUCATION IN ORTHOPAEDIC SURGERY*

INTRODUCTORY REMARKS

By A. R. Shands, Jr., M.D., Wilmington, Delaware, *Chairman*

Alfred I. du Pont Institute of the Nemours Foundation

In 1944, The American Academy of Orthopaedic Surgeons and The American Orthopaedic Association appointed a six-man Joint Committee on Post-Graduate Training, with Dr. Ralph K. Ghormley as Chairman. (Members representing The American Academy of Orthopaedic Surgeons are Joseph S. Barr, M.D., Ralph K. Ghormley, M.D., and J. Spencer Speed, M.D. Members representing The American Orthopaedic Association are Fremont A. Chandler, M.D., Paul C. Colonna, M.D., and Philip D. Wilson, M.D.) In 1946, I was added to the Committee as a seventh member and was made its Secretary. The first objective of this Committee was to increase the facilities for orthopaedic training, in order to provide for the medical veteran desiring to become a qualified orthopaedic surgeon. This was accomplished by reviewing the approved training services in the United States, asking that as many of these as possible increase the number of residents, and recommending the establishment of new training services in hospitals and clinics without approved training, but with the necessary facilities and staff.

In two years' time the number of training services was increased from approximately 79 to 238, and the number of residents from 253 to 726. The American Medical Association and The American Board of Orthopaedic Surgery had previously agreed to grant temporary approval to all of the new services recommended for approval by this Joint Committee. In the fall of 1948, twenty-eight orthopaedic surgeons visited these 238 services, reviewed the training, and submitted reports. These reports resulted in the changing of the types of approval of approximately fifty services. Following this review of orthopaedic training, it was decided that the next work of the Committee should be a conference on the methods and types of post-graduate education. The Conference today is the result of this decision.

The last report on residencies in the *Journal of the American Medical Association* for May 14, 1949, lists 257 hospitals with approved training in orthopaedic surgery. These hospitals have 787 available orthopaedic residencies, which are approved as follows: for adult work, 195; for children's work, 110; for fractures, 110; and for basic sciences, 110.

In the survey of 232 hospital services in 1947, information was obtained on the questionnaires (Question 21) concerning the responsibility of the orthopaedic service for fractures, osteomyelitis, et cetera. This information, which has never been published, is thought to be most appropriate to present at this Meeting. It is as follows:

Question 21. *Is the orthopaedic service responsible for*

	Wholly	Partially	Not at all	Total Answering Question
1. Fresh fractures	198 (83.5%)	35	13	237
2. Acute osteomyelitis and pyogenic arthritis	230 (91%)	18	5	253
3. Soft tissue of extremities	135 (51%)	98	29	262
4. Peripheral-nerve injuries	71 (31%)	65	93	229
5. Acute poliomyelitis	109 (56.4%)	31	53	193
6. Amputations	127 (54.3%)	86	21	234
7. Surgery of the hand	116 (50%)	86	31	233

What is the objective of resident training? It is to create an orthopaedic surgeon (1) who has surgical skill and judgment,—that is, one who is good with his head as well as his hands; (2) who has a curiosity for the unknown and a desire to improve the known; (3) who has an understanding for the patient as a whole and his restoration to normal or as nearly normal living as possible; (4) who has a full appreciation of where the orthopaedic surgeon fits into the general scheme of medical practice; and (5) who will develop into a leader in his medical community. If this type of orthopaedic specialist is created, the training is well done, and it is the wish of your Chairman that there will develop in the discussions this afternoon the formula for training which will result in just this type of doctor.

There is definitely no one best method of resident training, but there is undoubtedly a better method or an improved method for every training service. Out of this Conference it is hoped will come an [illegible] pattern of training for each of the 257 approved hospital services. At the Conference held last y[illegible]

* Conducted at the Annual Meeting of The American Orthopaedic A[illegible] Colo[illegible] Colorado, May 18, 1949.

dergraduate Education, Dr F H Arestad of the Council on Medical Education and Hospitals of the American Medical Association stated that, while a model plan can be developed as a guide, "it should not be developed as a fully standardized plan, because you can never really standardize teaching itself" We shall try this afternoon to develop the ideas for a model plan, but definitely with no thought of attempting to standardize this plan This model plan then can be used by the hospitals and clinics as a guide, in order that the same general pattern of training may be received by all orthopaedic residents

Before calling on the first speaker, the Chairman wishes to express a word of appreciation to our Board, which has done so much for our present training program This, through its past President, Dr Guy A Caldwell, and its members, has stood for high standards of training Requirements for training have been laid down, particularly for the basic sciences, which may have seemed to some to be too strict and perhaps unnecessary, but there is no doubt that, although these requirements may have worked a hardship on a few, they have resulted in the best orthopaedic training for the greatest number This cannot help but result in better orthopaedic practice throughout the nation, and in time to come will create more solid ground for orthopaedic surgeons to stand upon We all owe a debt of gratitude to our Board for what they have accomplished for the specialty, and I wish to express to the Board particularly the thanks and appreciation of the Post-Graduate Training Committee

In the preparation of the program, an attempt has been made to have all direct and indirect phases of training presented We are to hear also from those representing the Board, the American College of Surgeons, and the American Medical Association It is regretted that time will not permit everyone to speak who has something to add

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A PROGRAM FOR TRAINING IN ADULT ORTHOPAEDIC SURGERY AND FRACTURES

BY ALAN DEFOREST SMITH, M D , NEW YORK, N Y

New York Orthopaedic Hospital

The title implies that the service is limited to adults, but it is preferable when possible to include children, in order that complete training may be given in one institution, without sharply dividing the case The organization of the service will depend upon a number of factors, one of which is the size of the hospital If possible, it is preferable to segregate the fracture cases in separate wards This facilitates their treatment and leads to better results The fact that they frequently are emergencies and that special equipment is necessary create special problems which set them somewhat apart from the usual orthopaedic cases This does not mean that a separate fracture staff is necessary, for in fact it is better that the staff rotate in the care of the two groups

The minimum period of training for residents in order to satisfy the Board requirements is six months for fractures and one year for adult orthopaedic surgery, but those who wish to limit their training to adults are obliged to spend an additional year on such a service instead of one year with children This is apt to cause some complication in the organization of the residency At the New York Orthopaedic Hospital we have a three-year program, which is set up as follows The first year, the assistant resident is on an orthopaedic service for both adults and children The second year, six months are devoted to the study of basic sciences and six months to fractures We purposely have deferred the basic-science period until the second year, because we believe that there then will be a better understanding of what is needed and a better appreciation of the courses The third year is spent as a fellowship, during three months of which each man is senior resident For the remainder of the year he works in the Out-Patient Clinic and in the operating room, and attends rounds and conferences

Thus there are twelve men always in training, with two completing their service each six months Each man is assured of receiving his minimum of three years of training without the possibility of being dropped at the end of the first or second year, as happens in the pyramidal system, in which one resident serves for a year or more Opportunity for continued training for those showing unusual aptitude is offered in the form of a limited number of senior fellowships These fellowships also are of great advantage to the Hospital, in enabling it to obtain the services of men who have had a residency in another hospital and who wish to spend an additional year in this Clinic We find that the residents bring with them many new ideas and help to give us a broader point of view

Education in the resident stage is best carried out by practical instruction at rounds, conferences, staff meetings, and in the operating room and clinic Some more formal mode of instruction seemed advisable, however, and, after trying various methods, we have decided upon a series of seminars each year, conducted by various members of the staff These are informal and are carried out by the method of questions and answers, rather than as didactic lectures The residents and fellows are expected to do some reading in preparation for them and to be prepared to enter intelligently into the discussions

In addition to somewhat extensive instruction in pathology, given during the basic-science period, pathological conferences are held weekly. During the second year, in addition to the study of the histology of bone tumors, the men attend a weekly bone-tumor clinic at the Memorial Hospital. Regular conferences are held several days a week with the roentgenologist, at which the current films are discussed. Additional practical instruction in roentgenology is given during the basic-science period, and includes positioning of patients.

During the first year the assistant residents attend the out-patient clinics as much as possible, but the major part of this experience is gained during the third year, when they are not restricted as closely by ward responsibilities. We regard this as one of the most important parts of the entire program, and feel that too much time cannot be spent in this phase of the work. In addition to the general clinics, there are special ones dealing with scoliosis, club-foot, arthritis, neurology, and back conditions. Each man, by rotation, participates in these special clinics at some period during his training.

Each man is required during his three-year period to carry out some clinical investigation or research project and to prepare a report, to be read at a staff meeting. Biographical sketches of important figures in the history of orthopaedic surgery are prepared by the members of the resident staff, and usually one is read at each monthly staff meeting. Some excellent papers have been written, which have been stimulating to seniors and juniors alike.

THE IDEAL CURRICULUM IN CHILDREN'S ORTHOPAEDIC SURGERY

BY WILLIAM T. GREEN, M.D., BOSTON, MASSACHUSETTS

Children's Hospital

The essentials for a training program in children's orthopaedic surgery are:

1. Sufficient diversified representative clinical material;
2. Capable orthopaedic surgeons in the children's field to spend sufficient time in teaching the men who are in training.

The training program must be adapted to local situations, so that an ideal curriculum is difficult to discuss. What would be ideal in one situation would not be ideal in another. However, certain comments may be made regarding an ideal plan of training. I would not, by choice, call it a curriculum, which I do not believe graduate training should be.

In general, I believe that the best type of training represents an evolution from the apprentice system, in which, in effect, the apprenticeship is to a hospital service with all its attendant diversification rather than to one individual. Essentially, the institution should be centered about the problems as they arise on the service. Ordinarily, the problems presented by the patients, singularly and in the aggregate, serve as the axis about which training revolves. Progressive responsibilities and experiences should be given the trainee, as he is ready to receive them. Didactic lectures should be minimal, although, when judiciously used, they may have a place. On the other hand, conferences and exercises in which the trainees participate are valuable, and form an essential part of any program.

Certain specific comments may be made under appropriate headings.

The Hospital in the Training Program

As previously indicated, the first requirement is that the hospital engaged in the training program must have a sufficient number of patients, representing all types of orthopaedic problems at all ages during the period of growth. It should have large out-patient clinics, not only to give experience in the types of problems which are presented in such a clinic, but also to allow continued observation of patients who have been discharged from the in-patient division.

Ideally, a children's orthopaedic service is best located in a hospital which is concerned with all types of pediatric problems, both medical and surgical, although at all times the orthopaedic service must maintain its autonomy. Such a relationship is valuable from the standpoint of consultation with the various services. It is likewise an advantage for the hospital to be a participant in undergraduate teaching and graduate teaching in other specialties. By contact with all divisions, and in particular with the residents in training in other specialties in pediatrics, the trainee develops a breath of approach to the problems of childhood which might otherwise be missed.

Residency Assignments and Rotation

A service employing one resident is at a great disadvantage. This can be compensated for in part by the visiting orthopaedic surgeon spending an inordinate amount of time with each resident in turn. It is preferred to have at least two residents on a junior-senior relationship, both in time of service and experience.

dergraduate Education, Dr F H Arestad of the Council on Medical Education and Hospitals of the American Medical Association stated that, while a model plan can be developed as a guide, "it should not be developed as a fully standardized plan, because you can never really standardize teaching itself" We shall try this afternoon to develop the ideas for a model plan, but definitely with no thought of attempting to standardize this plan This model plan then can be used by the hospitals and clinics as a guide, in order that the same general pattern of training may be received by all orthopaedic residents

Before calling on the first speaker, the Chairman wishes to express a word of appreciation to our Board, which has done so much for our present training program This, through its past President, Dr Guy A Caldwell, and its members, has stood for high standards of training Requirements for training have been laid down, particularly for the basic sciences, which may have seemed to some to be too strict and perhaps unnecessary, but there is no doubt that, although these requirements may have worked a hardship on a few, they have resulted in the best orthopaedic training for the greatest number This cannot help but result in better orthopaedic practice throughout the nation, and in time to come will create more solid ground for orthopaedic surgeons to stand upon We all owe a debt of gratitude to our Board for what they have accomplished for the specialty, and I wish to express to the Board particularly the thanks and appreciation of the Post-Graduate Training Committee

In the preparation of the program, an attempt has been made to have all direct and indirect phases of training presented We are to hear also from those representing the Board, the American College of Surgeons, and the American Medical Association It is regretted that time will not permit everyone to speak who has something to add

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A PROGRAM FOR TRAINING IN ADULT ORTHOPAEDIC SURGERY AND FRACTURES

By Alan DeForest Smith, M D , New York, N Y

New York Orthopaedic Hospital

The title implies that the service is limited to adults, but it is preferable when possible to include children, in order that complete training may be given in one institution, without sharply dividing the case The organization of the service will depend upon a number of factors, one of which is the size of the hospital If possible, it is preferable to segregate the fracture cases in separate wards This facilitates their treatment and leads to better results The fact that they frequently are emergencies and that special equipment is necessary create special problems which set them somewhat apart from the usual orthopaedic case This does not mean that a separate fracture staff is necessary, for in fact it is better that the staff rotate in the care of the two groups

The minimum period of training for residents in order to satisfy the Board requirements is six months for fractures and one year for adult orthopaedic surgery, but those who wish to limit their training to adults are obliged to spend an additional year on such a service instead of one year with children This is apt to cause some complication in the organization of the residency At the New York Orthopaedic Hospital we have a three-year program, which is set up as follows The first year, the assistant resident is on an orthopaedic service for both adults and children The second year, six months are devoted to the study of basic sciences and six months to fractures We purposely have deferred the basic-science period until the second year, because we believe that there then will be a better understanding of what is needed and a better appreciation of the courses The third year is spent as a fellowship, during three months of which each man is senior resident For the remainder of the year he works in the Out-Patient Clinic and in the operating room, and attends rounds and conferences

Thus there are twelve men always in training, with two completing their service each six months Each man is assured of receiving his minimum of three years of training without the possibility of being dropped at the end of the first or second year, as happens in the pyramidal system, in which one resident serves for a year or more Opportunity for continued training for those showing unusual aptitude is offered in the form of a limited number of senior fellowships These fellowships also are of great advantage to the Hospital, in enabling it to obtain the services of men who have had a residency in another hospital and who wish to spend an additional year in this Clinic We find that the residents bring with them many new ideas and help to give us a broader point of view

Education in the resident stage is best carried out by practical instruction at rounds, conferences, staff meetings, and in the operating room and clinic Some more formal mode of instruction seemed advisable, however, and, after trying various methods, we have decided upon a series of seminars each year, conducted by various members of the staff These are informal and are carried out by the method of questions and answers, rather than as didactic lectures The residents and fellows are expected to do some reading in preparation for them and to be prepared to enter intelligently into the discussions

THE IDEAL CURRICULUM FOR BASIC-SCIENCE INSTRUCTION IN ORTHOPAEDIC SURGERY

By Guy A Caldwell, M D, New Orleans, Louisiana
Tulane University

In the course of graduate training for orthopaedic surgery, review of those portions of the basic sciences which are related to orthopaedic surgery is of fundamental importance A thorough knowledge of the anatomy, pathology, and physiology of the musculoskeletal system is essential for a comprehensive *diagnosis* of the lesions encountered, and an equal understanding of bacteriology and biochemistry is required for efficient *treatment* of the patient and his impaired function

Ideally, this basic-science knowledge should be acquired with each new orthopaedic condition that is encountered It is a generally accepted principle of medical teaching that, as the student learns to recognize the clinical picture of a lesion in a given patient, he will retain this knowledge best if he immediately reviews the entire background of the problem presented Such a review includes detailed examination of the anatomy of the parts involved, the pathological and histological alterations commonly observed, and the physiological changes encountered If infection is present, or if the metabolism is altered, the student should consult the medical literature and study the laboratory techniques in bacteriology and biochemistry, in order to direct measures of treatment intelligently

In the ideal curriculum, therefore, anatomical and pathological specimens should always be available for dissection, and free access should be had to consultants in physiology, bacteriology, and biochemistry, so that the student may discuss with them the problem in hand This would enable the student to see the complete picture of the lesion, and thus to understand more intelligently the progress in treatment The impression gained would then be indelible, and each similar problem encountered, with its minor variations, would be readily associated with the first one and equally well retained

Such an ideal plan requires

1 A limited, but varied, number of patients with orthopaedic problems,

2 Availability of anatomical and pathological material, adequate library facilities, and competent instructors or consultants in physiology, bacteriology, and biochemistry,

3 Sufficient time free from routine hospital duties to enable the student to do the necessary dissections and other studies

However ideal such a plan of instruction may be, it obviously is impractical in view of the obligations of a resident to the hospital and in the care of patients assigned to the orthopaedic service It is likewise impossible for graduate schools to provide instructors who can be available at all times to assist the student with problems in physiology and biochemistry Nevertheless, close integration of a broader knowledge of the basic sciences with the clinical care of the patients should be the working principle

Hospitals with orthopaedic services approved for three years of training, which are connected with medical schools, can most nearly approach this ideal plan of integrating the basic-science instruction with the clinical care of patients The medical school should have at least the potentialities for anatomical and pathological specimens for dissection, there probably are adequate library facilities, and usually instructors in physiology, bacteriology, and biochemistry, who can be prevailed upon to assist in the solution of orthopaedic problems However, the mere existence of such facilities and consultants will not guarantee their accessibility to the student There must be an *organized plan* for the student to follow, an *interest and stimulus* to prompt him to seek the knowledge, and *sufficient time* for him to acquire this fundamental background

The general plan for the trainee to follow should be formulated by the orthopaedic staff in conferences with teachers of the basic sciences The interest and stimulus must be furnished by the staff, who, on ward rounds, at conferences, and in the operating rooms, take every opportunity to review the fundamental background of each case discussed The time to be allowed residents and fellows must be arranged by agreement with hospital authorities, and must not be confined to evenings off duty and holidays

It is important that all biopsies and specimens removed at operation be reported in detail at staff conferences, it is helpful for the surgeon to identify the anatomical structures encountered in making an operative approach, and to demonstrate to his assistants the gross pathological changes revealed through this exposure Review of roentgenographic and laboratory findings and discussion of the difficult cases in conferences supplement the basic knowledge of the graduate students However, if these are the only opportunities in the basic-science phases of orthopaedic entities, the students will be woefully lacking in many essentials At most, such instruction gives them an incomplete picture of a few common conditions Therefore, a plan should be adopted which will cover *all* the conditions met in orthopaedic practice The graduate student will need the help of anatomical dissections, pathological demonstrations, and seminars in bacteriology, biochemistry, and physiology to acquire the necessary background for many problems which are encountered infrequently even on a large orthopaedic service

Acceptable programs for providing basic-science instruction have been developed by many of the institutions, and, although they vary considerably as to distribution of time and arrangements for giving

instruction, all of them embody the foregoing fundamental requirements They have a clearly defined program which seeks to cover the entire field, they have laboratory facilities and specimens available for dissection, and they provide instructors, either from the orthopaedic staff or basic-science teachers, or both, to conduct seminars and conferences, finally, they schedule a definite time in which the trainee may do this work In some institutions, this phase of instruction is confined to one day a week throughout the three-year period of training In other cases, the greater part of the first-year resident's time is devoted to the basic-science program In still other instances, an intensive program is arranged to cover a period of six months, during which time the resident has no regular hospital duties

Poor and unacceptable basic-science training still prevails in far too many hospitals These hospitals generally fall into two groups In the first group the program provides time (approximating six months) during which the trainee is released from other duties A schedule is outlined whereby the trainee attends clinicopathological and radiological conferences, spends certain hours in laboratories of anatomy and pathology, and attends lectures in physiology and biochemistry However, investigation often reveals that the conferences contain little relating to orthopaedic surgery, the anatomy and pathology are but a general review of material presented to undergraduate students by the preclinical faculty, and the lectures in physiology and biochemistry are routine, general ones given at the undergraduate level No selection of those parts of the basic sciences relating to orthopaedic surgery has been made by the orthopaedic staff, and the staff does not participate in the instruction Much that is given the trainee is far afield or completely irrelevant, because the orthopaedic staff has dodged its responsibility

The second group of poor programs in the basic sciences consists of those supposedly integrated with the clinical work, but actually containing little more than a few crumbs of knowledge dropped by the surgeon in the course of routine ward rounds, while operating, or during staff conferences The resident is advised now and then to "read up" on this or that, or to "run over to the dissecting room" and review this or that surgical exposure As the time for Board examinations approaches, the staff man urges the trainee to "get someone in the Department of Pathology to show you some bone-tumor slides" No organized, comprehensive plan has been evolved by the staff, sufficient time has not been set aside, and, by precept and example, the orthopaedic surgeons indicate that the fundamental background of basic-science knowledge is not particularly essential Their attitude is expressed in the remark sometimes heard "It is unnecessary to spend so much time on basic-science studies, that knowledge will come to you as you go along with your clinical work " Such an attitude on the part of the senior surgeons fails to impart the necessary interest and stimulus to the resident to make him seek the fundamental knowledge he sorely needs

The ideal program of basic-science instruction will not be realized until staff members themselves appreciate its value and importance enough to assist in formulating an organized plan of instruction for the residents, to help with the demonstrations and seminars, and to take every opportunity to discuss in the clinical conferences the fundamental background of each new condition encountered Usually, assistance is needed from full-time instructors in the basic sciences, but the subjects covered by the instructors should be carefully chosen and their application to orthopaedic surgery should be explained by an orthopaedic surgeon

As a means toward better teaching of the basic sciences, medical centers should develop orthopaedic surgeons with special interests and ability in one or another of the basic sciences When we have several men in each center qualified as orthopaedic surgeons or interested in orthopaedic surgery—one who knows and teaches anatomy, as does Inman of the University of California, another who has learned pathology of bones and joints, as did Bennett of the University of Illinois, and another who is thoroughly familiar with bacteriology and wound infections, as is Meleney at Presbyterian Hospital—the basic sciences will be taught ideally To this end, future staff members who are now residents or young assistants should begin special investigations in one or another of the basic-science fields There should be funds to provide facilities and to subsidize their work Thus, in a few years, each of these orthopaedic surgeons will have a broad and thorough knowledge of one of the basic subjects He will contribute greatly to staff interest and can give proper instruction in that branch to the residents

In conclusion, the ideal program for basic-science training should include

1 A senior staff which appreciates the importance of this phase of training,

2 An organized, comprehensive program prepared by the orthopaedic staff, with assistance from basic-science teachers,

3 A working schedule for residents, which will provide adequate free time for personal study and preparation, and attendance at the scheduled conferences, demonstrations, and seminars,

4 A staff which will develop all the fundamental background of each new clinical entity as it is encountered on ward rounds and in the operating room, and will thus arouse the interest of the residents in thorough basic-science training,

5 Hospital and medical-school administrators who will secure funds to provide part-time salaries and laboratory facilities for young staff men, so that they will become interested in anatomy, pathology, physiology, and biochemistry

THE IDEAL CURRICULUM OF RESIDENT TRAINING IN A UNIVERSITY CLINIC

By Carl E Badgley, M D, Ann Arbor, Michigan

University of Michigan

I agree with all that has been said Now we come to the problem of the curriculum in a University Clinic It seems to me that the problem is simply that in a University Clinic we are, in addition, teaching There is an opportunity, which Dr Caldwell has just suggested, of utilizing our University Centers for the purpose of acting as a mother center, and, through these, of developing an exchange service so that we may send our men to other institutions for a period of time for the purpose of having them acquire knowledge in a particular phase of our work We have had such an arrangement for several years with Dr Abbott at California and, more recently, with Dr King at Stanford, we have also an exchange service with other hospitals In addition, it is possible to utilize the University Centers for the teaching of the basic sciences to residents from outlying areas

I agree with Dr Green that one of the greatest things in the training of orthopaedic residents is the relationship with the men on other services We need the broad knowledge that the men of the other services can impart to our men We are very much pleased that such has been the case in the University Hospital in Ann Arbor, where all the surgical departments are closely interrelated We do not regard ourselves as specialists particularly and, regardless of the surgeon, each group requires the same amount of training, the men are all on an equal level and they have many things which they can talk over There are so many interdigitations in the various types of work in orthopaedic surgery which require knowledge of neurosurgery, thoracic surgery, vascular surgery, and various other fields, that such a plan of training, I believe, is absolutely essential

It is important to have close cooperation with the department of medicine Various problems arising in an orthopaedic department, such as thrombophlebitis, the fatigue syndrome, arthritis, gout, et cetera, need medical consultation

Concerning pathology, I must pay tribute to the Orthopaedic Board I think the Board has done a remarkable job in the stimulus it has given our residents to learn pathology There is no doubt that, since the Board initiated this requirement, our men have been much more interested in pathology Our departments of pathology and of anatomy are now appreciative of the need that our men have for this training, and we are developing a relationship we never had before We have didactic teaching in pathology, which I think is good However, the didactic teaching should not be on the level of one older pathologist to another, but should be on the level of the younger pathologist who is acquiring the knowledge which the older pathologist possesses Lectures are given twice a week by just such a pathologist, and it has been valuable to all of us We also have the daily examination of autopsy material

Our relationship with the Department of Pediatrics has been close and is most satisfactory Daily conferences in roentgenology are extremely stimulating These related activities are all important in the development of our specialty and in the training of our men

In our department, embryology is now playing an important role We have had a project on the development of fascia, with work which has progressed so that it is of basic value It has been done on foetal specimens at the University Hospital in our Surgical Department

Concerning training in anatomy, merely the dissecting of the human body has never seemed to me to be the answer One must do far more than dissect a cadaver We allow three full months in the Department of Anatomy, in which time we anticipate that the resident will work on a research problem The residents are utilized for the purpose of teaching There is nothing more stimulating to the individual than the fact that he has to teach and at the same time has to know what he is teaching If he can have this opportunity, it is far better than simply dissecting In addition, our men teach surgical anatomy, which is also of great value to them This is taught in the third year

The teaching responsibilities in the University Clinic, of course, are minimal when these men are in training, but we utilize these residents to a considerable extent in the teaching of nurses, in various other departments, such as social service, in rehabilitation, and also in our out-patient clinics for the teaching of juniors and the teaching of the sophomores in fractures I think the most important thing in the training of men is to give them a sense of responsibility It is the sense of responsibility that stimulates residents to do their best work

The residents also have the stimulus of learning to speak while standing on their feet, which is a very important part of training The residents present their cases, completely worked up with a full résumé, at weekly conferences from nine to twelve on Saturday mornings This is entirely their responsibility Similarly, we have a fracture conference at which they present their cases Having the individual responsibility of presenting a patient at conference makes it necessary for the resident to get the most out of the case

THE IDEAL CURRICULUM OF RESIDENT TRAINING IN A PRIVATE CLINIC

BY J. S. SPEED, M.D., MEMPHIS, TENNESSEE

The Campbell Clinic

The fundamental purpose of an orthopaedic residency is to train the young surgeon for the private practice of orthopaedic surgery. The ideal training program is found in neither the strictly charity hospital nor the strictly private hospital and clinic, but is found where experience is obtained in both types of institutions. For the resident in the private clinic and hospital, it is desirable, if possible, to add experience on a charity orthopaedic service, as well as in the allied specialties of plastic and neurological surgery. It is, of course, preferable that the charity services be directed by the same staff which controls the private clinic, so that the direction and character of the work will be of a uniform quality. However, if the charity service is directed by another staff, there will be a diversification of viewpoint, which is also of value.

By securing training in the private clinic, the resident can learn much of future value as regards the business side of medical practice, the practical aspects of handling patients, and the fundamental principles of planning treatment, which will conserve the patient's finances and yet keep his welfare uppermost. The type of patient seen in a private clinic and the diagnostic problems presented frequently differ in some respects from those seen on a charity service; consequently, the training gained in a private clinic will carry directly over into private practice.

The staff responsible for resident training in a private clinic must, of necessity, see that the training is well rounded and includes adequate instruction in the basic sciences. Too frequently the energies of the resident are consumed in work which does not promote his education and training. The schedule of training in the small private clinic cannot always be broken down into distinct services in which each of the major phases of orthopaedic surgery is given its proper representation; it is necessary, therefore, that a definite effort be made to see that the training offered the resident be properly balanced and complete.

The resident may obtain the necessary training in the basic sciences by attending an organized course in a graduate school of medicine or by integration of the basic sciences throughout the three years of residency. In the latter case, physiology and biochemistry can best be taught in conjunction with the medical phases of orthopaedic surgery, including the preoperative and postoperative care of the patients. Lectures on the various phases of the basic sciences should be given either by the staff or by members of the medical school faculty. Surgical pathology can best be taught by a correlation of the clinical, roentgenographic, and operative findings of the individual cases with the gross and microscopic study of the tissue removed at surgery. On the medical service at the beginning of the residency, an intensive review of surgical pathology in general and of orthopaedic pathology in particular should be carried out.

An especially valuable phase of the training offered by the private clinic is the opportunity for taking histories and making physical examinations. Here the resident will "work up" the patient, order and review the roentgenograms and laboratory studies, and formulate his own impressions as to the correct diagnosis and treatment. Whenever possible, he should be present at the time the staff man sees and examines the patient, reviews the roentgenograms and laboratory findings, analyzes all data brought out, and finally discusses the case with the patient. In this way, the resident has the advantage of learning the line of reasoning which the staff man uses in determining the proper treatment in the individual case, for treatment in many instances must be adapted to the individual and his circumstances. The resident should have the opportunity of assisting at operation on the patients he has worked up, seeing them postoperatively in the hospital, and later seeing them when they return for check-up examinations.

During the first year of training, the resident should work entirely under the direct supervision of the clinical staff, the staff being responsible for all decisions, all operations, and all after-care. Later, as his experience increases, it is desirable that the resident's responsibility be increased, to include if possible an adequate amount of individual operative work.

The danger of a single point of view, particularly as regards treatment, must not be overlooked. This can be obviated to a large extent by regular literature meetings, at which the current orthopaedic literature is reviewed, and presentations on assigned subjects are discussed. In a strictly orthopaedic clinic, attendance at general hospital staff meetings and clinical-pathological conferences should be encouraged.

In our own private Orthopaedic Clinic and Hospital, an effort has been made to combine the advantages of training in a private clinic with those of a charity service. Over the years, a training program has been evolved which encompasses all phases of orthopaedic surgery, as well as training in the basic sciences and certain aspects of neurological and plastic surgery. An outline of this training program is offered as an example of how a private clinic and hospital can be integrated into a resident-training program.

In addition to experience with the private adult and with children's orthopaedic and fracture cases, there are available the facilities of a forty-bed hospital for crippled children, the state crippled-children's services with their active surgical service, a sixty-five-bed hospital for crippled adults, a city-hospital service of forty beds (chiefly for acute trauma), a poliomyelitis service in the city isolation hospital, and a fifteen-bed in-patient cerebral-palsy unit. One day a week, the out-patient clinics of the crippled children's ar

adults' hospitals are conducted under supervision There is also an affiliation with a neurosurgical clinic and a plastic surgeon, to provide services in the orthopaedic aspects of these specialties The residents are actually responsible for the conduct of the charity services and they perform a majority of the surgical procedures upon these patients, always under close supervision

There is a weekly staff conference, usually lasting two hours, at which pertinent roentgenograms and pathological preparations are studied and reviewed in the light of the clinical features of the case A weekly lecture series is conducted, forty weeks a year These lectures, each two hours in length, are planned over a three year period to include both clinical orthopaedic subjects and the basic sciences, the clinical lectures are given by the Clinic staff, while the basic-science lectures are given by preclinical teachers of the medical school

At the present time, the training program is arranged as follows

First Year

1 Pathology and medical service in the private Clinic and Hospital, three months This includes a study of all material going through the Pathology Laboratory, and a systematic study of bone pathology, including tumors While on this service, the resident assists with the preoperative and postoperative care of the Hospital patients, and works in both the Clinic and Hospital on arthritis and peripheral-vascular cases

2 Assistant in operating room and work in the private Clinic, six months

3 First assistant in the operating room and resident in orthopaedic surgery in the private Hospital, with responsibility for daily ward rounds, weekly progress notes, and dressings, three months

Second Year

1 Assistant resident, crippled children's service, three months
2 Assistant resident, crippled adults' service, three months
3 Resident, crippled adults service, three months
4 Fellowship in neurosurgery, three months

Third Year

1 Fellowship in plastic surgery, three months
2 Resident, crippled children s service, three months
3 Assistant resident, city hospital (charity) service, three months
4 Resident, city hospital (charity) service, three months

RESIDENT TRAINING IN A VETERANS ADMINISTRATION HOSPITAL *

By Dana M Street, M D , Memphis, Tennessee

Veterans Administration Medical Teaching Group, Kennedy Hospital

These remarks refer specifically to the present program at Kennedy Veterans Administration Hospital Kennedy Hospital was built for the Army during the War and was one of the largest General Hospitals It was acquired by the Veterans Administration in 1946 and the excellent equipment was retained It is at present operated as a 1,400-bed General Medical and Surgical Hospital

The Surgical Service is comprised of sections in all of the major specialties, each of which is headed by a member of the respective specialty board The same applies to the medical and other services in the Hospital, so that consultations are readily obtained The large, full-time staff is also on hand for conferences and seminars on all phases of medicine Paraplegia forms a separate section With 250 beds, Kennedy is one of the four paraplegic centers in the country for veterans

The Orthopaedic Section and training can perhaps best be described by following the resident through the program The Orthopaedic Section contains 144 beds, and has been approved by the Board for two years' training in adult orthopaedic surgery, fractures, and basic science Three months of neurosurgery have been added, making a total of twenty-seven months

To examine this in more detail, the resident spends his first six months as Junior on a fifty-three-bed ward for clean orthopaedic surgery and fractures Two such wards, or 106 beds, are devoted to these cases The case material seen by the resident is exceedingly good The anticipated burden of osteomyelitis and back cases has not materialized, of the 2,130 patients admitted during the past two years, 1,017 or 50 per cent have had fractures, only 190 or 10 per cent have had osteomyelitis, and 358 or 15 per cent have been back cases of all sorts Patients with major traumatic injuries are brought from all parts of Tennessee,

* Published with permission of the Chief Medical Director, Department of Medicine and Surgery, Veterans Administration, who assumes no responsibility for the opinions expressed or the conclusions drawn by the author

Arkansas, and Mississippi. Of the fractures, 8 per cent. are non-unions and 10 per cent. are compound.

The three months spent on the Paraplegia Section offer the resident an unusual opportunity to gain insight not only into severe injuries of the spine, but also into problems peculiar to paraplegics. Paramount is the prevention and treatment of decubitus ulcers which, besides loss of protein, may also lead to osteomyelitis and infection of the adjacent joints. Other problems are urinary-tract infection, fractures, and myositis ossificans. Since most of the paraplegics require braces, the resident becomes familiar with the Brace Shop, employing twelve brace mechanics and averaging over 100 new braces per month. During this three months he is also assigned to the service of Physical Medicine, and becomes familiar with physical therapy apparatus, such as the Hubbard tank and the bar-bells of DeLorme, as well as occupational-therapy techniques and rehabilitative procedures, such as ambulation of amputees, stair-climbing for paraplegics, their getting from wheelchair to bed, from wheelchair into bath tub, et cetera.

The three-month period spent on the Neurosurgery Section is optional, but is felt by most of the residents to be very valuable because of the close relationship of the two specialties. Here the resident sees spinal cord tumors, treats head injuries, and studies the mechanisms of pain. Early disc cases are treated conservatively in the Orthopaedic Department. Simple disc operations are done by the neurosurgeons, and those requiring fusion are done by both services as a combined procedure.

Although much basic science can be taught on the ward, such as protein metabolism, fluid and electrolyte balance, and blood replacement, we feel that six months under the direction of the Pathology Department is of value. The work is in autopsies and surgical specimens, supplemented by dissection of extremities, lectures at a neighboring institution, and reading. We believe that the resident's work should not be limited to orthopaedic material, since there is much to be learned in the fundamental principles of inflammation, neoplasia, and trauma from cases of other services. We are of the opinion that pathology cannot well be combined with ward work, because insufficient time remains for study. Contrary to the impression of some, the Veterans Administration resident does not check in at eight and out at five o'clock, but works day and night as the need for his services exists. His reading time for clinical subjects alone is limited.

The resident then returns to the orthopaedic wards, spending three months as Senior on a ward containing a twenty-bed section for osteomyelitis and an eighteen-bed section for bone tuberculosis. These sections are well separated from each other and from the clean wards. The tuberculosis cases are drawn from all of the southeastern states and form a good teaching series.

During the final six months, the resident is Senior on one of the fifty-three-bed clean wards. Having assisted in a wide variety of operations as a Junior, he now has complete charge of the ward, does most of the surgery on his patients, and directs their preoperative and postoperative treatment. The Chief of the Section assists him with his first case of each type, after which, depending upon his aptitude, he is allowed to operate without direct supervision. He is thus given gradually increasing responsibility as he develops the capacity to handle it. The more extensive procedures are done by the Section Chief.

Besides the ward work described, all of the residents participate in an out-patient clinic, two afternoons per week. Hospital patients of other services are seen in consultation at this time. Grand rounds are conducted one morning a week, when every patient on the Section is seen. An x-ray conference and an orthopaedic conference are held each week.

Although appointments are on a yearly basis, the entire twenty-seven months described are available to all of the residents unless they prove incompetent. An additional six months is available to a selected 50 per cent. in which to round out their experience. In the past two years we have performed 948 open operations. Of these, 247 or about 25 per cent. have been done by myself, 25 per cent. by the Senior Resident, and 50 per cent. by the Senior Ward Officers. A man staying two years may then expect sixty or more major operations and, with the additional six months, 120, plus many minor procedures. Therefore, the service is neither a pyramid nor a straight service, but rather a semi-pyramid. It avoids the chief drawback of the pyramid type—namely, the casting out of men with little or no operative experience—while at the same time the Senior Resident receives a widely representative group of cases. Although the program is patterned after the Board requirements, we are fundamentally interested in training the residents to practise orthopaedic surgery, and not merely to meet their requirements.

In summary, the strong features of the service are its excellent reconstructive and traumatic material, experience with paraplegics, complete facilities for physical medicine and rehabilitation, and effective mechanism for follow-up study. The weak points are the paucity of material in the older age group and in childhood. The older group is increasing yearly, and the lack of children is partially compensated for by an affiliation with a children's hospital, which takes care of 50 per cent. of our residents.

In order to carry out successfully such a program of gradually increasing responsibility on the part of the resident, it is imperative that he be not oversupervised by a large, fully trained staff. A full-time appointment for the Supervisor is advantageous, permitting him to divide his time more equally between clinical work, research, and teaching. Clinical work is necessary to maintain diagnostic acumen, technical skill, and insight into the patient's problems. Research advances the frontier and constitutes a necessary proving ground for new procedures. Teaching provides one of the best incentives for keeping up with advances and, as Hippocrates said, is a moral obligation.

RESIDENT TRAINING IN AN ARMY HOSPITAL

By Colonel Milton S Thompson, Medical Corps, United States Army
Brooke General Hospital, Fort Sam Houston, Texas

The precipitous demobilization at the end of the last War threatened to leave hospitals full of ailing patients and empty of trained doctors The prewar specialists, like Major General Norman T Kirk, held responsible administrative positions, the younger men had had no specialty training, the graduate professional-education program was needed This program was started in 1947 and is designed to provide specialty training for Army doctors

Orthopaedic training is provided in six of the Army's fourteen named General Hospitals These six are Walter Reed General Hospital in Washington, Oliver General Hospital in Augusta, Georgia, Fitzsimmons General Hospital in Denver, Letterman General Hospital in San Francisco, Brooke General Hospital in San Antonio, Texas, and Valley Forge General Hospital in Phoenixville, Pennsylvania The professional personnel of these Hospitals consists of the assigned staff, plus the attending staff of qualified civilian specialists Their effort to maintain the highest standards has earned the approval of the civilian councils and boards concerned with maintaining these standards

As of January 25, 1949, 143 Regular Army Medical-Corps Officers have been certified as diplomates of American Specialty Boards[1], four of whom were certified in orthopaedic surgery

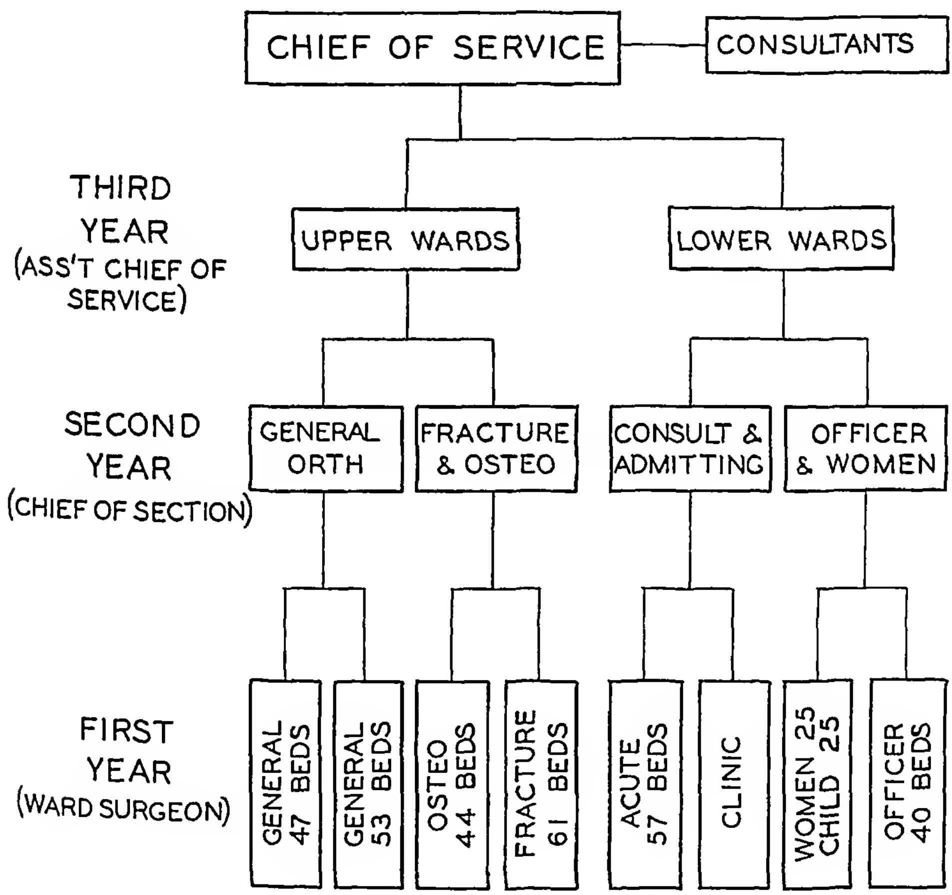

Fig 1

At these residency-training hospitals, interns are selected from graduates of approved medical schools who are physically qualified for appointment in the Medical Reserve Corps These men are given a one-year rotating internship, which includes one month on the Orthopaedic Service Residents are selected from interns and from Regular Army Medical Officers who apply and who have the desired educational qualifications and aptitude The residents are being assigned for three years of training, and rotate through positions of increasing responsibility

There are some variations in the division of the services at the six hospitals, but typical is the organization at Brooke General Hospital (Fig 1)

Formal teaching ward rounds are conducted There are weekly Clinico-Pathological Clinics and Tumor Clinics, well-planned courses in anatomy with cadaver dissection, courses in pathology, and formal lectures on other basic-science subjects, given by qualified instructors Monthly professional staff meetings, journal meetings, and problem clinics are attended, and the residents are welcome at x-ray, medical, surgical, and other conferences The aim of this training is to encourage the residents to think in terms of long-range results

The hospitals selected for residency training have not only fine physical plants with the most modern and complete equipment procurable, but abundant clinical material of all ages and kinds Since they are General Hospitals serving wide areas, they are each at the "bottom of a funnel", and, since their patients include not only soldiers, but also dependents, veterans, and retired personnel, the age and sex variation, as well as proportionate pathological training, is comparable with that of any civilian general hospital

At Brooke General Hospital last year, 1,609 babies were born and 13,719 children were seen in the Out-Patient Department Of these, about 600 visited the Orthopaedic Children's Clinic The retired officers and soldiers and their dependents, as well as the veterans of the earlier wars, furnish material for training in geriatrics

TABLE I

Orthopaedic Surgery[2]

Hospital	In-patients Treated	Out-patient Visits	Operations Major	Operations Minor	No of Residents Authorized	No of Residents Present	Beds Allotted
Brooke	2,796	3,619	835	116	14	6	347
Fitzsimmons	1,136	2,931	702	139	8	5	264
Letterman	2,006	2,232	769	136	15	8	450
Oliver	1,815	1,052	549	497	14	4	561
Walter Reed	912	4,168	775	374	14	3	300
Valley Forge	1,083	707	753	152	11	0	370

We are enthusiastic about the graduate-education program, and hope that it will accomplish the purpose for which it was designed In the field of orthopaedic training, we feel that it is definitely justifying its existence Regular Army doctors have acquired skills and experience and have gone to staff hospitals in this country and abroad In the two years which have elapsed since the inception of the program, Army residents in orthopaedic surgery have benefited from the experience of participation in a program which last year offered 9,748 patients and 5,797 operations in the six General Hospitals giving orthopaedic-residency training

REFERENCES

1 Army Medical Corps Specialists Bull U S Army Med Dept, 9 299, Apr 1949
2 Office of The Surgeon General, Department of the Army Report from Clinical Data for Residency Training, Army General Hospitals

RESIDENT TRAINING IN A NAVY HOSPITAL

By Joseph S Barr, M D, Boston, Massachusetts

Reserve Consultant in Orthopaedic Surgery, Bureau of Medicine and Surgery, Navy Department

The Navy has conducted a graduate medical-training program for its regular medical officers since 1920 At the close of World War II, plans were made for expanding this training program, utilizing the facilities of Naval hospitals for residency training At the present time, United States Naval hospitals at San Diego, Long Beach, and Oakland, California, Bethesda, Maryland, Philadelphia, Pennsylvania, St Albans, New York, and Chelsea, Massachusetts, are approved for residency training in orthopaedic surgery The approval is for adult orthopaedic surgery, fractures, and basic sciences No Naval hospitals are approved for training in children's orthopaedic surgery At the present time, there are a total of twenty-nine Naval medical officers in resident training in orthopaedic surgery,—fourteen in Naval hospitals, and fifteen in civilian training centers There are seven men at the first-year level of training, *thirteen* at the second-year level of training, and nine at the third-year level of training Although only one Naval medical officer is now certified by the American Board of Orthopaedic Surgeons, several others have completed the requir

ments for Part II of the examination, and the Bureau of Medicine and Surgery expects to continue assigning medical officers to the training program in sufficient numbers so that, within a reasonable length of time, there will be a well-trained orthopaedic surgeon certified by the Board in each of the larger Naval hospitals.

The training program at the individual hospitals is similar to that at any of our better civilian institutions. The medical officers who are in the training program have volunteered for it. They have been carefully selected on the basis of ability; they have had adequate preliminary surgical training. In most of the Naval hospitals, civilian consultants bear a major part of the responsibility for the training program. Each resident is expected to spend at least a year in a civilian institution in children's orthopaedic surgery.

I believe that the Naval program is well organized to meet the needs of the Navy, and that it compares favorably with the training obtained in many, if not most, civilian institutions.

SPECIAL TRAINING THE RESIDENT SHOULD HAVE IN CEREBRAL PALSY

BY ROBERT A. KNIGHT, M.D., MEMPHIS, TENNESSEE

The Campbell Clinic

Within recent years, a better understanding of the problems of the cerebral-palsy patient and his treatment has been encouraged, largely through the efforts of Dr. W. M. Phelps of Baltimore. In the past, there has been little to offer the patient with cerebral palsy other than surgery, and even this, in the light of our present knowledge, was in many instances ill-advised.

The treatment of the cerebral-palsy patient does not fall into the field of pure orthopaedic surgery alone, but overlaps into the fields of physical medicine, pediatrics, and neurology. Thus, anyone professing to treat intelligently the patient with cerebral palsy must master certain fundamental principles of these other specialties, in addition to those within his own realm, if he is to evaluate the case accurately and direct care along all the necessary lines.

By nature of his background training, the orthopaedic surgeon is best fitted to care for the cerebral-palsy patient, and it thus becomes our problem to plan the training of the resident so that he may, during his period of formal training, master the fundamentals of diagnosis and treatment. This may be accomplished in either of two ways.

The first method consists of attendance at an organized program in cerebral palsy. At the present time, the most highly developed teaching program is in operation at the Children's Rehabilitation Institute, under the direction and supervision of Dr. Phelps. As it is set up, it consists of three months' work, and includes experience in the various rehabilitative measures in addition to organized lectures, experience in the private office, and attendance at cerebral-palsy clinics. This special training is recommended for those men who have a special interest in the field and who contemplate being responsible for more than an average amount of work with crippled children, including the organization and conduct of a cerebral-palsy clinic and treatment center.

The second method, which will be most practical for the majority of the residents, is by the inclusion of adequate basic training in the principles of cerebral palsy during the year's work with crippled children. This can be gained by attendance at a weekly cerebral-palsy clinic, regular work in a cerebral-palsy unit associated with the children's hospital, and formal lectures covering the pathology, clinical types, and methods of treatment. During the course of a year, the resident should have gained a good basic knowledge of the subject, including the re-educative phases, as well as the proper place of both bracing and surgery.

Training of the cerebral-palsy patient can be carried out on either an in-patient or day-student basis; if personnel and funds permit, both types of training can be given. In planning a unit, multiples of fifteen patients are used, since a therapist can adequately carry a case-load of fifteen children with moderately severe handicaps; somewhat more than this number can be treated if their handicaps are less severe.

The staff needed for a fifteen-bed in-patient unit is as follows:

Medical director, part time (an orthopaedic surgeon with special training in cerebral palsy)
Physical therapist (with special cerebral-palsy training)
Occupational therapist (with special cerebral-palsy training)
Speech therapist (part time)
School teacher

Practically, the in-patient unit should function as an active training unit, admitting patients for periods of three months or longer. Certain patients can, after an initial period during which their training program is being set up in the unit, have the training carried out by the parents at home; others, because of their peculiar treatment needs, will require prolonged training at the treatment center. Before the patient [illegible] d to return home, his mother should come to the center for instruction so that she can intelligent [illegible] the child's therapy.

In large cities, the less severely handicapped children can be brought to the center daily Their program is similar to that of the in-patients, but the cost of this day-unit type of training is less in that residence facilities are not required, the fact that the children are not taken from the home for a long period of time is advantageous from a psychological standpoint

An in-patient unit of fifteen children, with a staff as described above, is in operation in conjunction with our own teaching program The unit is closely integrated with the resident-training program, the residents on the children's service attending the weekly conference held by the director of the unit, as well as making daily visits to the unit The experience and training which these residents gain would, of course, be greater and more diversified if the unit were larger, but it has been our experience that even a fifteen in-patient unit, with an active follow-up clinic, serves as a valuable training ground for the resident

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SPECIAL TRAINING FOR THE RESIDENT STAFF IN INFANTILE PARALYSIS

By Raymond E Lenhard, M D , Baltimore, Maryland

Johns Hopkins Hospital

The relationship of poliomyelitis to resident training is a vast topic There are many facets to the problem, any one of which, if pursued to the end, would entail an extremely large amount of information A general outline might be briefly stated as follows

1 Etiology
2 Epidemiology
3 Symptomatology
   A Differential diagnosis
4 Pathology
   A Changes in central nervous system
   B Changes in muscles
5 Prognosis
6 Treatment
   A Acute stage
   B Convalescent stage
7 Bracing for treatment and for rehabilitation
8 Operative Phase
   A Correction of deformities
   B Improvement of function
9 Vocational Rehabilitation

One might suppose that it would be unnecessary to dwell too much with a resident staff on the problem of etiology, epidemiology, symptomatology, and pathology They should know from their textbooks and medical training the basic facts, or as much as is known, of the disease The diagnosis for a resident staff should be a simple problem

They might be impressed with the prognosis and with the statement that many of the cases are unrecognized, but that, in those which have definitely been diagnosed, the recovery rate is rather high In 60 per cent of recognized cases, recovery is complete, another 20 per cent of patients recover with a minimum of residual weakness or disability About 2 per cent have marked residuum, to the point where wheelchairs are required It is in the other 18 per cent that most of the problems arise in regard to prolonged treatment

The residents, unless they are associated with a hospital for contagious diseases or one having contagious wards, will probably have very little opportunity to see the earliest stage of the disease, and may not have contact with patients for several weeks after the onset of the disease However, they should be taught the use of a respirator and the need for tracheotomy

They should become well acquainted with treatment at the convalescent stage, with the measures of physical therapy that are used, with the judicious use of heat, massage, and exercise, and with careful handling of the muscles and extremities involved Some knowledge of how to record the progress of patients and of the muscle testing required for such records might be a part of the program

Prophylactic measures during the recovery phase are essential, in an effort to prevent deformities or to diminish the amount of deformity of joints The residents should know the fundamentals of the bracing and splinting of extremities in the prevention of deformities, and the problems connected with such bracing when the patients are permitted to be ambulatory

When deformities exist, the teaching should include the mode of production of deformities as well as methods to correct them by muscle transplantation, tenodesis, and arthrodesis Such broad statements need more specific description, but the after-care of poliomyelitis is essentially a problem of individual patients and the best teaching is given at the bedside Since the disease leaves characteristically a spotty weakness, the

deformities may be multiple, involve any joint, and be associated with varying degrees of muscle weakness

The resident staff should also be acquainted with the fact that the poliomyelitis patient needs not only physical rehabilitation, but mental adjustment as well, and that, throughout the whole course of therapy, one should bear in mind the problems which may arise in regard to vocational rehabilitation

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SPECIAL TRAINING THE RESIDENT SHOULD HAVE IN THE FITTING AND MAKING OF BRACES AND PROSTHESES

By Atha Thomas, M D , Denver, Colorado

University of Colorado School of Medicine

In reviewing orthopaedic literature through the years, one gains the impression that, as knowledge and interest in open surgical procedures increase and new surgical techniques develop, there has been a proportionate diminution in interest in the problem of orthopaedic braces and appliances In spite of recent advances in the development of graduate orthopaedic teaching, sufficient effort or interest has not been shown in any organized or comprehensive instruction in the prescribing and fitting of braces, artificial limbs, and other orthopaedic appliances This lack of instruction is evidenced by the confused and limited knowledge of the subject on the part of many of the younger orthopaedic surgeons This deficiency became especially apparent when the military services established their own brace and limb shops during World War II

Except in some of the larger institutions which have their own brace shops, little opportunity or time is available for the orthopaedic resident to receive instruction in orthopaedic appliances, and, even when a shop is available, little effort is made to organize formal instruction on the subject This is especially true as regards artificial limbs There are few modern texts on the subject, and the literature is meager and not readily available

Too often braces are prescribed with little knowledge of the fundamental design and construction of the brace and with very vague ideas as to its purpose and function, this problem being left largely to the judgment and decision of the appliance-maker In addition there rarely is adequate supervision of the fitting of the appliance and instruction in its use, in order to make sure that it properly fulfills the purpose for which it was designed These matters all should be the responsibility of the prescribing physician, but too often they are left largely to the brace-maker or limb-maker

The relationship of the physician and the appliance-maker has been aptly compared to that of the supervising architect and the building contractor To prescribe and fit an orthopaedic appliance properly, the physician must not only possess a thorough understanding of the purposes of the brace, but also some knowledge of fundamental brace design and fabrication, materials available, and joint and lock mechanisms Such knowledge is best gained by formal instruction, as well as by observation and experience in the shop

Decisions as to the type of design or material used in braces are often made from habit or custom, rather than from a careful analysis of the individual patient's needs Such considerations as age, general physical condition, extent of involvement, economic and social status, and length of time the brace will have to be worn are important factors in the selection of the design and material used Judgment in these matters is attained through long experience or by adequate instruction

In order to carry out such teaching properly, close cooperation between the physician and the appliance-maker is essential Personal acquaintance with some of the leaders of the orthopaedic-appliance industry convinces me that they are eager to cooperate in such efforts, and I believe that it is to the mutual advantage of all concerned that this should be done Well-organized instruction and demonstrations in fundamental engineering principles, brace design, simple metallurgy, shop practices in metal, wood, and leather work, principles of measurement, and fitting are all desirable in such a teaching program I am sure that considerable teaching talent is available within the industry The members of the orthopaedic-appliance industry are eager to improve their own standards and to organize and enlarge their training facilities, they believe that this can best be accomplished by cooperation with, and by the assistance and encouragement of, orthopaedic surgeons

The instructional course in brace-making given by the Mellon Institute and University of Pittsburgh Medical School for both physicians and appliance-makers last fall was most worth while, and is a good example of such cooperative effort I understand that the course is to be repeated this fall in a slightly different form

The efforts of the Academy in cooperation with the Army, Veterans Administration, and the orthopaedic-appliance industry in preparing a comprehensive Atlas on Braces and Artificial Limbs is also most commendable, the Atlas, when published, will furnish valuable material for the teaching of residents In addition, however, it is highly desirable that a formal teaching program be devoted to orthopaedic appliances, a curriculum being set up to include lectures and demonstrations and possibly even some shop experience It is only by such a program that this subject, so essential in orthopaedic practice, can be taught adequately

RESEARCH, PUBLICATIONS, PHYSICAL MEDICINE, AND OTHER SPECIAL SUBJECTS IN A RESIDENT-TRAINING PROGRAM

By Fremont A. Chandler, M.D., Chicago, Illinois

University of Illinois

Research and Publications

The rush and glamor of an ever-widening clinical experience is attractive to every resident, as it is to most practising orthopaedic surgeons. Research and the publication of scientific papers consequently have been relegated to a minor role in many courses for training of residents. Only late in their course do most of these surgeons begin to appreciate the need and satisfaction of investigative effort. Many enter active practice, hoping to devote sufficient time to serious study, little realizing that facilities and guidance are no longer at their disposal. Their economic advancement stifles them further and they join the ranks of imitators well disposed to allow others to advance the science of their specialty.

The desire for true knowledge must come from an inherent curiosity, leavened with some degree of skepticism for available data. Fire of this nature is instilled into the resident only with great difficulty by hard working mentally agile preceptors. The usual course of collegiate and medical education fails in high degree in the accomplishment of this phase.

How may we function best in correcting this situation which confronts us?

1. Clinical research depends largely upon the study of patient records, past and present. The assignment [illegible] review of some specific orthopaedic entity to the new resident will give him an opportunity of [illegible] the shortcomings of his predecessors and will emphasize the need of intelligent and accurate [illegible].

2. Although [illegible] residents feel capable of mastering big problems, it is usually desirable to initiate their [illegible] under the direct guidance of some productive worker.

3. [illegible] of case reports, supplemented by reviews of the literature, affords an opportunity for the [illegible] acquainted with library technique and with the various publications especially related [illegible].

4. The [illegible] these case reports and the active participation of the resident in clinical conferences adds [illegible] interest in this phase of training.

5. The [illegible] a thesis brings out latent ability which may otherwise remain hidden.

Special training [illegible] the following fields is of value.

Physical Medicine

It is difficult [illegible] size specific subjects in this field, for the practice of physical medicine employs techniques [illegible] border on psychological methods of therapy. These are proper if employed [illegible].

[illegible] little is known regarding the actual physiological response of tissue to the various stimuli that training in [illegible] field must be clinical in nature. This would indicate that the resident might well become a temporary member of the Department of Physical Medicine, actually participating in the administration of the prescribed [illegible] cedures. By doing so, he will appreciate the merits of technique and will be in a position to prescribe [illegible] more specifically. Familiarity with the use of the thermocouple, the electromyograph, and the numerous [illegible] ans of recording circulatory changes will enable the resident to recognize the opportunities of clinical application as he comes into contact with patients.

Instru[illegible] members of the Department of Physical Medicine is desirable. This should come early in the period of orthopaedic training.

Roentgenology

The extensive use of the roentgen ray in orthopaedic surgery makes this subject of major importance. To properly appreciate the intricacies of roentgenology as it serves the purpose of orthopaedic diagnosis, a knowledge of photographic technique and of the actual manipulation of roentgenographic equipment is most desirable. Although the final film is the immediate need of the orthopaedic surgeon, familiarity with the complex techniques required in its production will be beneficial. This can come only through actual use of the equipment. Nothing is of more value than serving as a technician for a short period.

Interpretation of roentgenograms is, of course, the major problem. Training in this phase is best accomplished by close contact with the roentgenologist and clinician, through the medium of frequent conferences.

Neurology and Rheumatology

Needless to say, experience and knowledge in these fields is of vital importance, but it may best be acquired through day-to-day contact rather than by isolated courses of instruction. Certainly neurological entities must be recognized by the orthopaedic surgeon, for many are reflected through dysfunctions of muscles and joints. The principles of neurosurgery should not be overlooked.

THE GRADUATE SCHOOL OF MEDICINE

Course in Orthopaedic Surgery and Its Curriculum

By Jesse T. Nicholson, M.D., Philadelphia, Pennsylvania

University of Pennsylvania Graduate School of Medicine

The Graduate School of Medicine at the University of Pennsylvania was established in 1916 by merger of the Medico-Chirurgical College and Hospital, the Diagnostic and Howard Hospitals, and the North American Sanatorium, and by various philanthropic gifts. Its purpose was to provide "basic" graduate study in the well-recognized clinical specialties. This graduate study was "intended to lay a foundation and to prepare for appropriate clinical and thesis studies to succeed the basic studies."

The clinical and thesis studies may lead to a graduate medical candidacy, providing the Faculty are convinced that the candidate is qualified to practise the clinical specialty concerned. "The Faculty becomes convinced ... in either of two manners: (a) By the fact that the candidate has become a certificant ('diplomate') of the related American Board for the certification of such clinical specialists, or (b) that the candidate has fully completed all the detailed preceptorship or fellowship requirements, including certification as to special clinical qualifications by the officially designated preceptor(s) or fellowship director(s).

"Preceptorships may proceed in several manners: hospital residentships, or resident or visiting hospital or clinical fellowships or assistantships, or assistantships in private special clinical practices of preceptors in approvable part-time combination with one or more of the foregoing hospital associations." They have as common features: "(a) Approved study facilities, (b) an approved preceptor who cooperates with the preceptee and the University, (c) a duration of two or more years, if the candidate be engaged solely in his preceptorship studies, (d) a duration of three or more years if the candidate engages in clinical (or other occupational) pursuits in addition to his preceptorship studies, (e) an academic credit of two thousand hours or more in two years or more of study, and no credit being given for private practice of the candidate, (f) preparation of an approvable thesis, involving an acceptable degree of original investigation pertaining to the clinical field concerned in the candidacy, (g) the preparation of the thesis must be authorized and active while the practical credits are being accumulated, but it is not necessary that the thesis requirement shall have become fulfilled completely at the time that the practical requirements become fulfilled,—an extension of time for the fulfillment of the thesis requirement being allowable at the joint discretion of the preceptor, dean, and faculty, (h) periodic preceptorial and faculty approval of the practical and thesis studies as they proceed, (i) final general preceptorial and faculty approval of the special practical status which the candidate has attained, and approval of his completed, unpublished, thesis."

For a Master's degree in (medical) science, two calendar years of clinical and thesis studies are required. For a doctorate in (medical) science, one to three years are devoted to research in the field of the specialty concerned.

"Separate basic studies are provided for each of the (seven) clinical specialties currently accorded major recognition by the school's curricula: internal medicine, pediatrics, neurology-psychiatry, dermatology-syphilology, radiology, surgery, gynecology-obstetrics, orthopaedics, urology, ophthalmology, otolaryngology, physical medicine, anaesthesiology, orthodontics, oral surgery-oral anaesthesia, oral medicine-periodontics and prosthetics."

The Department of Orthopaedic Surgery was established in 1923. The Chairman or Vice Dean was Dr. DeForest P. Willard, who retired from this chair in 1946. His observation and experience were responsible for the evolution of the course as presented today.

The school term extends from October to May. The enrollment is restricted to twelve. This number facilitates instruction in anatomical dissection and microscopic pathology, permits small sections for ward rounds, surgical theater, and out-patient clinic, and allows better evaluation of student potentialities by the instructors.

The schedule comprises thirty-two weeks. Each week has thirty-seven hours of assigned work, giving a total of 1,184 hours for the term. These assigned hours of work are broken down as follows: 586 hours are devoted to basic studies, 210 of the basic-study hours are occupied by lectures and clinical demonstrations in the correlated clinical-science course. This course is given by the separate departments of Physiological Chemistry, Pathology, Physiology-Pharmacology, Bacteriology and Immunology, and Physical Anthropology in the Graduate School of Medicine. These staffs combine to give an integrated course. The following is the present general arrangement of lectures:

1. Kidney (26 lectures)
2. Circulation (23 lectures)
3. Heart (15 lectures)
4. Blood (13 lectures)
5. Alimentary Tract (17 lectures)
6. Liver and Gall Bladder (11 lectures)
7. Metabolism and Nutrition (17 lectures)

8 Endocrines (20 lectures)
9 Nervous System (25 lectures)
10 Physical Medicine (6 lectures)
11 Lungs (22 lectures)
12 Microbiology (15 lectures)

In addition to this correlated clinical-science course, lectures in special physiology (14 hours) and biochemistry (12 hours) are given by the departments to the students in orthopaedic surgery Separate courses are given the orthopaedic students in anatomical dissection and cadaver surgery (192 hours) and in gross and microscopic pathology of bones, joints, muscles, and tendons (160 hours)

Two hundred seventy-three hours are spent upon subjects related or responsible for orthopaedic complaints and methods of rehabilitation Radiology occupies sixty-seven hours, neurology, ninety-six hours, neurosurgery, four hours, peripheral-vascular diseases, twenty hours, anaesthesia, sixteen hours, arthritis, twenty hours, physical medicine, ten hours, occupational therapy, six hours, plastic surgery, twenty hours, blood dyscrasias, six hours, dietary deficiencies, four hours, and bone metabolism, four hours

Three hundred twenty-three hours are directly devoted to orthopaedic surgery For much of this schedule, the student group of twelve is divided into three sections The clinical observations are facilitated by the affiliated teaching of the following hospitals and institutions

Philadelphia Children's Hospital For children's surgery, out-patient clinic, and acute orthopaedic illnesses of children,
Philadelphia Shriners' Hospital For children's surgery and ward rounds,
The Widener School for Crippled Children For kinesiology, poliomyelitis, and cerebral palsy,
The Alfred I duPont Institute of the Nemours Foundation For clinics on deformities of children,
The Presbyterian Hospital For plastic surgery,
Naval Hospital For amputations,
Valley Forge General Hospital For hand surgery,
Philadelphia General Hospital For fractures,
Temple University Hospital For ward rounds,
The University Hospital For clinical conferences,
Graduate Hospital For adult surgery and out-patient clinic

Collateral reading in unassigned hours is stimulated by the assignment of an orthopaedic subject of general interest Each week, before the student conference, one member of the group presents an up-to-date summary of his assigned subject with a pertinent bibliography If the presentation is approved, it is mimeographed for distribution to other members of the class

The limitations of the course are

1 The students are at all stages of their required three years of orthopaedic training
2 Little opportunity is afforded to begin or to continue a research problem
3 But six-months' credit is given by the Board of Orthopaedic Surgery for a scholastic year
4 There is no integration between the course and the additional years of resident training required by the Board of Orthopaedic Surgery

Some progress has been made in the latter instance Two general hospitals and one clinic have sent their residents to the Graduate School for the basic course in orthopaedics for the past three years With such a plan projected with other hospitals and clinics, the students might, by such a reciprocal arrangement, be enabled to meet full requirements of The American Board of Orthopaedic Surgery while completing research investigation that would entitle them to a degree of Master of Medical Science from the Graduate School of Medicine

NOTE Quotations are taken from the Announcement for Session, 1949–1950, Graduate School of Medicine, published by the University of Pennsylvania

WHAT CONSTITUTES A SATISFACTORY PRECEPTORSHIP TRAINING?

BY J ALBERT KEY, M D, ST LOUIS, MISSOURI

Washington University

A preceptorship type of training is not an easy way to become an orthopaedic surgeon The candidate who chooses this is usually one who, for economic reasons, does not find it possible to complete the formal orthopaedic program required by our Board Such a candidate is apt to be a serious student who has more than the average allotment of ambition and energy He should have an acceptable medical education, plus a

least one and preferably two years of training in general surgery It is also desirable, but not essential, that he have a year's formal training in orthopaedic surgery

Given this background, the candidate embarks upon a course which will eventually enable him to develop into an orthopaedic surgeon whose ability will compare favorably with that of his peers I use the term "develop" advisedly, because I wish to emphasize the fact that in the preceptorship, or what I prefer to call the informal, type of orthopaedic training, the candidate is no longer an undergraduate student whose tasks will be allotted to him each day, but is one who has begun his life's work and is largely on his own Much of what he does in the future will depend upon his own initiative, rather than upon an instructor He is not going to be run through an orthopaedic mill and be delivered to the community as a finished product It is for this reason that this type of training is suitable only for the candidate who has more than the average amount of determination He should also realize that the period of training will be prolonged

The amount of time which he should spend in informal training will vary with the ability of the candidate and with the opportunities for learning and experience which are afforded in his situation In an average situation, he should spend approximately twice as long in informal training as he would in formal training Under our present system, if he has had no formal orthopaedic training, he should plan on about six years of study and work before he is in a position to request examination with a view to certification by our American Board On the other hand, if he has had one year of formal training, he should plan on four years of informal training Since he will have been actively engaged in the practice of orthopaedic surgery during much of this time, it might be well for our Board to recognize this and to permit him to take his final examination at the end of his course of informal training, rather than after two additional years of practice

The candidate should associate himself with an established orthopaedic surgeon of recognized ability He will act as an assistant and receive a moderate salary, which will enable him to be self-supporting or partially so In the beginning, he will not contribute a great deal to the partnership, but, as he gains in knowledge and ability, his contributions will be more important and his monetary compensation will be increased

It is important that the senior member of the team—the preceptor, if you choose to call him that, although his status is far removed from that of a tutor—be genuinely interested in the development of his young associate If this is true, the candidate will not be exploited, but will be given ample opportunities for mastering his specialty He will be stimulated to study his textbooks and the current orthopaedic literature, and, from time to time, he will be advised to pursue comprehensive courses of reading on specific subjects in order that he may become familiar with the manner in which our present knowledge of orthopaedic surgery has evolved

The candidate will not be exposed to formal courses or laboratory demonstrations in the basic medical sciences, in a futile effort to repeat his first two years of medical school, but he will be encouraged to refresh and perfect his knowledge of the anatomy of the spine and extremities and to keep abreast of those advances in physiology, biochemistry, bacteriology, pharmacology, and pathology which are of interest to modern orthopaedic surgeons He will be stimulated to spend some time in the clinical laboratory of the hospital with which he is associated, and to study the microscopic preparations of the lesions which he encounters at the operating table

In clinical orthopaedic surgery, the candidate will at first observe, and then take the histories of and examine patients Then he and the senior member will go over these patients together and will discuss the diagnosis and treatment He will become proficient in the application of the various conservative measures used in orthopaedic surgery and in the successful handling of patients He will assist in operations, become skillful in the use of plaster-of-Paris and braces, and in the after-care of patients both in the hospital and after they leave the hospital

As the young man's knowledge and ability increase, he will be given more responsibility in the care of patients and will be permitted to perform the simpler types of operations, reduce the less difficult fractures, and to continue the treatment of these patients until the end result has been reached In doing this, he will have it impressed upon him that restoration of normal function is very often the object of his treatment In his efforts to attain this, he will learn the usefulness and the limitations of physical therapy

If a free clinic is available, he will be given an opportunity to work in this clinic and, when he is capable of performing such duties, he will be assigned to a ward service in the hospital If there is a medical school located in his community, an effort should be made to have the younger man assist in the instruction of students He should also be assigned some specific problem for investigation and study and, if he has a bent for either clinical or laboratory research, this should be encouraged and he should be allowed time to devote to the problem He should be encouraged to attend and participate in medical meetings, and should be given the opportunity to do so

Finally, as his judgment matures, he should be permitted to make decisions of increasing gravity and to assume responsibility for the solution of the more serious problems which are encountered in our specialty

Under such a regimen, I believe that it is possible to develop a man who, while not a walking encyclopedia of medical science, is a very satisfactory orthopaedic surgeon In fact, it has been done again and again The reason it is not done more frequently is because both the candidate and the preceptor must be men of exceptional character

RESULTS OF THE SURVEY ON THE REQUIREMENTS FOR BASIC-SCIENCE TRAINING

By Francis M McKeever, M D , Los Angeles, California
The American Board of Orthopaedic Surgery, Inc

For several years The American Board of Orthopaedic Surgery has insisted that, during the three-year period of specialized training in orthopaedic surgery, time equivalent to six months be devoted to training in the basic sciences, the Board has so outlined its training requirements This can be satisfied by integrating the basic-science training in the three-year period (which is considered preferable) or, in instances where instruction in basic sciences is not available, it has been possible to satisfy this requirement by a course of six months devoted to the study of the basic sciences

In order to evaluate this requirement, a poll was made of 500 individuals who had taken one or both parts of the examination of The American Board of Orthopaedic Surgery during the years 1946 to 1948 The following questionnaire was sent to these 500 individuals

"Dear Doctor

The following questionnaire is sent to you in order that The American Board of Orthopaedic Surgery may evaluate its requirement of six months' resident training in the Basic Sciences It is hoped that you will answer the following questions in the spirit in which they are requested, giving your opinion as to the value of this requirement to you and any constructive criticism which you may consider pertinent

If you have not completed the examinations, your answers will have absolutely no bearing on your eligibility

1 Have you completed Part I examination?
2 Have you completed Part II examination?
3 How did you meet the Basic Science requirement?
   (a) Special course at University?
   Where?
   (b) Integrated with clinical training?
   Where?
4 If you took a special course in Basic Science, at what time in your resident training period did you take it, the end of 1st year, 2nd year, etc?
5 What benefits did you derive from your Basic Science training?
6 Additional comments

(Name)
(Address) "

Of the 330 individuals who had taken both Part I and Part II, 231 replied The questionnaire was also sent to 170 who had taken only Part I, 133 of this group returned the questionnaire A total of 364 questionnaires were returned

The questionnaires of those who had taken Part I and Part II, and of those who had taken only Part I, were analyzed separately, as it was felt that the latter group might have a certain reticence in answering the questions This, however, did not prove to be the case

Twenty-five individuals, or 6 8 per cent of those who replied, disapproved of the basic-science requirement The percentage of those disapproving varied practically none in each group The requirement was approved by 93 2 per cent

Statistics—Part I Only Completed

1 *Total Number of Questionnaires Sent*		170	
2 *Total Replies Received*		133	
Integrated training	59		
Special courses	46		
Integrated and special courses	26		
None	2		
	133		
3 *Nature of Replies*			
Approved plan, with special comment		123	—93 2%
Approved plan, without comment		1	
Disapproved		9	6 8%
4 *Subjects Especially Approved*			
Anatomy	74		
Pathology	69		
Physiology	27		

Biochemistry	11
Bacteriology	2

5 *Special Courses*

Location	*No Attending*	*Location*	*No Attending*
Columbia University	8	University of California	1
Northwestern University	6	Alabama University	1
Pennsylvania University	4	Illinois University	1
Iowa University	3	Ohio State University	1
Washington University	2	University of Colorado	1
Kansas University	2	University of Texas	1
University of Buffalo	2	University of Toronto	1
Wisconsin University	2	Marquette University	1
University of Minnesota	2	College of Medical Evangelists	1
Tulane University	1	Kennedy Veterans Administration	
Oregon University	1	Hospital	1

6 *Approved Integrated Plan of Training*

Those who had had integrated course	21
Those who had had special courses	11
Those who had had both types of basic-science training	4
	36

7 *Approved Separate Course*

Those who had had special courses	3
Those who had had both types of training	1

(The reason expressed in the questionnaires for such approval was the "relief from the care of patients")

8 *Special Opinions*

One year of general medicine was advised by one man

Two individuals felt that basic science should not start until after one year of clinical work

Statistics—Part I and Part II Completed

1 *Total Number of Questionnaires Sent* 330

2 *Total Replies Received* 231

Integrated training	181
Special courses	38
No basic-sciences courses	12
	231

3 *Nature of Replies*

Approved plan, with special comment	208	—93%
Approved plan, without comment	7	
Disapproved plan	16	7%

4 *Subjects Especially Approved*

Anatomy	95
Pathology	87
Physiology	33
Biochemistry	12
Bacteriology	5
Pharmacology	1

5 *Special Courses*

Location	*No Attending*	*Location*	*No Attending*
Iowa University	11	New York University	1
Northwestern University	7	Temple University	1
Columbia University	3	University of Chicago	1
Tulane University	3	Wisconsin University	1
Southwestern University	2	Marquette University	1
Pennsylvania University	1	Howard University	1
McGill University	1	College of Medical Evangelists	1
Baylor University	1	Germany	1

6 *Approved Integrated Plan of Training*

Those who had had integrated training	37
Those who had had separate courses	5
Those who had had some of both types	4
	46

7 *Approved Separate Course*

Those who had had separate course

Those who had had integrated course

8 *Special Opinions*

Ten expressed opinions that basic sciences should not be commenced until after one year or more of clinical training It was felt that candidates would then be better oriented

Two believed general pathology was overemphasized

One believed training in neurology desirable

One believed training in general medicine desirable

The following conclusions seem justified from this survey

1 The basic-science requirement should be continued

2 Clinical residencies should not be accredited for basic-science training unless they present evidence of *personnel*, *equipment*, and *time allocation* for the adequate teaching of anatomy and pathology, and show evidence of an affiliation for the proper instruction in physiology and biochemistry by qualified personnel

3 Basic-science courses in a few teaching centers should be encouraged to continue, in order to supplement and round out the training of those individuals who do their clinical work in places inadequate for proper basic-science training In this way, no clinical facilities will be wasted

4 Basic-science courses which are given as a separate period of instruction should be so organized that the students are kept in some contact with clinical work during their instruction in the basic sciences This might be accomplished by having the students in basic science attend rounds twice weekly or serve a part-time clerkship on orthopaedic services in hospitals during their period of basic-science training

NOTE Unfortunately the comments of those filling out the questionnaires cannot be included here, due to lack of space

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THE AMERICAN COLLEGE OF SURGEONS

Training in Surgery and the Surgical Specialties

By Philip D Wilson, M D, New York, N Y

Hospital for Special Surgery

The interest of the American College of Surgeons in graduate training in surgery and the surgical specialties is a natural outgrowth of one of the principal purposes for which it was founded,—namely, the elevation of the standards of surgical practice in the United States and Canada Committees of the College began the study and discussion of different plans of surgical training as early as 1930 In 1936, the Board of Regents passed a resolution, requiring that applicants for fellowship in the College, who had received their qualifying medical degrees between the years of 1938 and 1944, should present evidence of having completed three years of hospital service following graduation, of which two years should have been spent in training in surgery or the surgical specialties

There was a further elevation of the requirements for admission to fellowship in the College in 1945, when the Board of Regents adopted a resolution requiring four years of hospital service for applicants who had graduated from medical school after 1945, of which three years should have been spent in training in surgery or the surgical specialties in hospitals approved by the College and in such study of the basic medical sciences as might be considered necessary In October 1948, the requirements for training in general surgery were raised to four years following internship

When the College, in 1936, decided that it must approve the facilities of a hospital for training in surgery or the surgical specialties, it became necessary to add inspection of the educational activities of the hospital to the investigation previously carried on to ascertain whether the hospital should be approved as complying with the program of minimal standards

In 1937, by action of the Board of Regents, a Committee on Graduate Training in Surgery was established, to which were appointed general surgeons and representatives of all of the surgical specialties The Committee was given the task of investigating and evaluating the opportunities for training in surgery and the surgical specialties in all of the hospitals in the United States and Canada As a member of that Committee since its beginning, I can testify that its members have taken their responsibilities seriously and have worked hard in reviewing and passing on the reports of training programs, submitted by the full-time field investigators The College has been fortunate in securing, on a short-time basis, the services of several young surgeons who have themselves recently completed training in surgery, so that they are familiar with the requirements for good training programs Their investigations have not been perfunctory inquiries into form, but have penetrated deeply into content as well

In order to avoid the necessity of frequent meetings of the Committee, the Director of Educational Ac

tivities of the College, Dr George H Miller, now causes to be sent to each of the members of the Committee full reports of the investigations of the training programs of hospitals that are applying for approval, as soon as they are received, and the members have the opportunity of passing on them without delay Approval is by unanimous vote and, if there is difference of opinion, the further consideration of that program is postponed until the next meeting of the Committee

To give an idea of the educational activities of the American College of Surgeons as represented here, I may point out that of the latest report, published in the approval number of its *Bulletin* in December 1948, I may point out that of the 2,561 hospitals which have been approved by the College's Hospital Standardization Department as complying with its minimum standard requirements, there were 310 hospitals with 738 graduate training programs which had been approved by the Graduate Training Committee Approximately 3,800 doctors were serving residencies in surgery or the surgical specialties in these hospitals

With respect to training in orthopaedic surgery, fifty-six programs in civil hospitals had received approval In addition, a considerable number of Government-operated hospitals were conducting approved programs, including five by the United States Army, one by the United States Public Health Service, seven by the United States Navy, and twenty-six by the Veterans Administration

There is one particular feature of the College program of evaluating graduate-training plans which needs to be emphasized, and which explains why the number of orthopaedic programs which have been approved by the College is smaller than that approved by the American Medical Association The College insists that for approval, a fully coordinated three-year training program should be carried out The Committee on Graduate Training feels that programs of one or two years cannot lead to progressive increase of responsibility on the part of the resident, in keeping with the increase in his experience and knowledge, and also that they leave the resident in doubt as to obtaining the additional period of training that he may require Furthermore, hospitals that offer training for periods of less than three years are generally not functioning in affiliation with a medical school or a medical center, or they would have been able to work out a coordinated three-year program in cooperation with other hospitals Generally speaking, such hospitals do not have well-organized departments and the training facilities are not so good as they should be

From this statement it can also be seen that many more hospitals have been approved for orthopaedic training than the fifty-six mentioned, because many of them have coordinated programs with other hospitals It is the feeling of the Committee on Graduate Training that it is better to withhold approval of short training programs and to encourage these hospitals either to work out coordinated three-year programs or to devote their educational activities to general instead of to specialty training

The reports on training programs in orthopaedic surgery which are sent in by the field investigators now include an analysis of the resident's experience, both with respect to clinical material and operations, in each of three major divisions—namely, pediatrics, surgery, and adult orthopaedics and fractures—as well as in the study of the basic medical sciences In addition, the reports include such statistical material on special work with poliomyelitis, club-foot, cerebral palsy, and scoliosis as may be obtained This type of comprehensive report gives a clear picture of the work being done and makes the task of evaluation fairly easy

What is most needed now is up-to-date factual material with respect to each of the approved training programs in the various hospitals This information should be available for the benefit of prospective residents, as well as for the American College of Surgeons, the American Medical Association, and the Specialty Boards To obtain such material, annual follow-up inspections are required, to report on changes that are made in the various programs and how they are working out Both the American Medical Association and the College of Surgeons are engaged in these investigative activities, with some duplication of each other's services A pooling of their efforts is greatly to be desired, leading to more effectual and comprehensive annual check-ups on these training programs Above all, agreement should be reached between these two great medical organizations with respect to the policy to be followed in approving and disapproving training programs, in order that the residents may not be confused, as they are at present, by differences in the lists of hospitals approved for training

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THE AMERICAN MEDICAL ASSOCIATION AND SPECIALTY TRAINING

By F H Arestad, M D , Chicago, Illinois

Council on Medical Education and Hospitals, American Medical Association

First, I wish to extend greetings from the Council on Medical Education and Hospitals and to express my own personal appreciation for the privilege and opportunity of meeting with you again

Since your last meeting in Quebec, the major survey of medical education sponsored jointly by the Council on Medical Education and Hospitals and the Association of American Medical Colleges has been organized and is well under way, under the full-time direction of Dr John E Deitrick, Associate Professor

of Medicine, Cornell University Medical College, and Director of Postgraduate Instruction of the Second (Cornell) Division, Bellevue Hospital, New York City This comprehensive study, which will extend over a period of three years, will be conducted under the supervision and guidance of the Survey Committee on Medical Education, consisting of the following members

Alan Valentine, Litt D, Chairman, President of the University of Rochester
Dr Arthur C Bachmeyer, Associate Dean, University of Chicago School of Medicine
Dr Herman G Weiskotten, Dean of Syracuse University College of Medicine
Dr Joseph C Hinsey, Dean of Cornell University Medical College
Dr Victor Johnson, Director of Mayo Foundation for Medical Education and Research
Dr Dean F Smiley, Secretary of the Association of American Medical Colleges
Dr Donald G Anderson, Secretary of the Council on Medical Education and Hospitals, American Medical Association

The Committee has stated that the objectives of the study are "to evaluate the present programs and determine the future responsibilities of medical education in the broadest aspect for the purpose of (1) improving medical education to better meet the over-all needs of the American people for the prevention of disease, the restoration as far as possible to health of all those who suffer illness or injury, and the maintenance of the best standards of physical and mental health of all the people, (2) assessing the degree to which medical schools are meeting the needs of the country for physicians, (3) promoting the advancement of knowledge in the field of medical science, and (4) better informing the public concerning the nature, content, and purpose of medical education"

From the nature and scope of the present survey, it is safe to predict that changes in the educational patterns will result in all of the major fields of medical education The advancement of scientific knowledge and the changing conditions of medical practice have brought into sharp focus a number of subjects which will require an adequate place in the medical curriculum Included in this group is the subject of nuclear energy and its application to medical practice and research Physical medicine and rehabilitation will also command the attention of medical educators, in view of the increased span of life and the associated problems of chronic and degenerative disease Social and economic factors must likewise be taken into consideration in future planning, as well as new concepts in relation to mental health, nutrition, preventive medicine, and other subjects It may also be anticipated that, in future years, the basic medical sciences will be more closely integrated with clinical medicine and that the position of the internship will be more clearly defined in its relationship to the clinical clerkship, residency training, and general practice In view of the interrelationship and interdependence of the various components of medical education, we may also look forward to further changes in premedical education and in the graduate and post-graduate fields

Since the meeting of your Association in Quebec, the Council on Medical Education and Hospitals has revised the Essentials of an Approved Internship and the Essentials of Approved Residencies and Fellowships The latter will, within a short time, undergo further revision, however, in order to incorporate the changes that have recently occurred with the establishment of the American Board of Proctology and the expansion of physical medicine into the broader field of Physical Medicine and Rehabilitation An American Board has also been established in Preventive Medicine and Public Health, thus increasing to eighteen the number of certifying boards approved by the Medical Council on Education and Hospitals

The general, or mixed, residency classification, previously included in the standards for residency training, has been discontinued, and in its place the Council has adopted specific requirements for residencies in general practice These are designed to meet the needs of medical graduates intending to enter general practice, and should preferably be organized as two-year programs, offering broad experience and training in the major fields of internal medicine, general surgery, obstetrics, pediatrics, and the ancillary services of pathology, radiology, and anaesthesiology It is not anticipated that residencies in general practice should be accepted as fulfilling any of the requirements for specialty certification To do so would defeat the main purpose of this program, which is to increase the number of well-trained general practitioners in this country and to induce more and more of the young physicians to enter the general practice of medicine

The plan for the temporary approval of residencies in specialties, adopted as an emergency measure to meet the increased postwar demand for residency training, has been discontinued by joint action of the Council on Medical Education and Hospitals and the Advisory Board of Medical Specialties The residencies approved on a temporary basis, as well as other educational services that have not been reviewed within the last two years, are now being evaluated by the inspection staff of the Council and a selected group of eleven regional inspectors This survey has progressed rapidly, and will probably be completed by the end of 1949 To supplement the program of hospital inspection, the American Board of Radiology is planning to conduct a further survey of radiological residencies, in cooperation with the Council on Medical Education and Hospitals The pattern for this type of study has already been established in the cooperative survey of orthopaedic residencies, conducted in 1947 by the Council, The American Orthopaedic Association, and The American Academy of Orthopaedic Surgeons

In the field of specialty training, we find at the present time an increasing interest in the development of hospital affiliations This trend is especially apparent in regional planning, and may in some areas involve

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The measuring and fitting of braces is too often left to the brace man. The young resident should be familiar with braces and their application. Dr. Thomas has stated that the relationship of the orthopaedic surgeon to the brace-maker should be as that of the architect to the builder. This is well expressed. I believe that on most services insufficient attention is given to instructing the resident in braces. A good knowledge of braces is important in dealing with all orthopaedic conditions, especially in the care of patients with cerebral palsy and infantile paralysis.

Dr. Smith has mentioned attending bone-tumor clinics. Few places are able to send their men to a Memorial Hospital, but still there are few institutions which do not have a tumor clinic in the vicinity which the orthopaedic residents could attend. Even if very little of the work in these clinics concerns orthopaedic tumors, the experience will be of distinct benefit. I like particularly what Dr. Smith has said about instruction in the technique and the positioning of patients for roentgenograms. This is something which few residents are taught, and there is certainly nothing more discouraging in the practice of orthopaedic surgery than poor roentgenograms, taken in the wrong position or at the wrong angle. Planned and scheduled conferences with the roentgenologist have been mentioned by several speakers, and should be a regular feature in all training programs.

I do not think that too much attention can be paid to teaching the residents how to speak while on their feet, as mentioned by Dr. Badgley, and the practical handling of patients—so important in private practice—as mentioned by Dr. Speed. Few services give special attention to these points. The correct method and form for the writing of papers should be included in the training. Each resident should be required to prepare a paper for publication during his training. Research problems should be encouraged, but not required. For some residents it will prove a great stimulus to later achievement, for others it will be lost time. The chief-of-service should evaluate as far as possible the investigative abilities of his resident staff and plan accordingly. Every service should require of the residents journal reading and preparation of a certain number of journal abstracts, and there should be regular journal-club meetings. In these conferences orthopaedic history should be included, as mentioned by Dr. Smith.

Before closing, a word should be said concerning the Government services. When the Veterans, Army, and Navy applied several years ago for approval of their newly established resident-training programs, it certainly was the belief of some of us that they would have great difficulty to develop services comparable to those of civilian institutions. What you have heard today from Dr. Street of the Veterans, Colonel Thompson of the Army, and Captain Barr of the Navy should allay all fears concerning the excellence of the training. They are not only measuring up to the standards of civilian training, but are giving a great deal more training in many fields, such as rehabilitation and the care of the paraplegic, than is being given in civilian institutions. The supervision of the work, with its volume and variety, is certainly adequate for good training. This information is most gratifying to those of us who have worked closely with the Surgeon Generals of the Army and Navy and the Chief Medical Director of the Veterans Administration during the last several years.

These are only a few of the pertinent facts from the discussions, as your Chairman sees them. Unfortunately, time does not permit elaborating further. As stated, no attempt should ever be made to standardize a pattern of training, but it is hoped that out of this Conference will come an improved method of training for every orthopaedic service engaged in the development and education of our orthopaedic surgeons of the future.

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समुद्रइव गम्भीरं नैव शक्यं चिकित्सितम् ।
वक्तुं निर विशेषेण श्लोकानामयुतैरपि ।।

—सुश्रुत संहिता

'*The Science of Medicine is fathomless* like the sea and can not be exhaustively narrated in thousands of couplets'

–SUSHRUT SAMHITA